METALLURGIA

THE BRITISH JOURNAL OF METALS.

MARCH, 1932. VOL. V., NO. 29.

Large Electric Furnace Installations

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Part II.—Heat-treatment of Steel.

In Part I, published in the last issue, some examples were given of the large electric annealing furnaces installed in the United States by the Electric Furnace Co., of Salem, Ohio. In this part further examples are given of the same firm's work as applied to general heat-treatment processes. A recent agreement with Messrs. Birmingham Electric Furnaces, Ltd., calls for complete interchange of patent designs and experience, so that all the designs described are now available in this country.

MANY of the furnaces employed for annealing can be used for other purposes. This is particularly the case with batch-type furnaces. Mechanically-operated furnaces are obviously most suited for the work for which they are especially designed—but even with these it is possible sometimes to use the same furnace for more than one process. Thus, the large counterflow furnaces for annealing forgings are equally suitable for carburising.

It is now proposed to describe a few typical installations used for the various kinds of heat-treatment required by steel, other than annealing (previously described in Part I.).

Carburising.

Carburising is a process made use of in many industries. It consists essentially of heating steel articles composed of low-carbon steel in a carbonaceous mixture. In this way the surface of the steel absorbs carbon and acquires the property, common to high-carbon steels, of being hardened by sudden cooling from above a certain temperature (AC_3 point). Carburising can be carried out with ordinary batch-type furnaces, but with this method the whole of the heat taken up by the charge is wasted when the charge is withdrawn and allowed to cool in the air. Counterflow furnaces were designed to minimise this loss, part of the heat of the finished charge being transferred to the ingoing charge. Unfortunately, this type of furnace has certain limitations which have prevented its general application in Great Britain. It is necessary for the efficient working of the counterflow furnace that it should be operated continuously with material requiring the same conditions of treatment; moreover, these furnaces are usually designed for fairly large outputs. It will thus be seen that the counterflow furnace, whilst eminently suitable for use in mass production plants where there is a constant flow of one type of material, is not adaptable for intermittent work where the size of article treated, or the time of treatment required are constantly varying. It is no doubt due to this fact that at the moment there is only one large counterflow type annealing and carburising furnace in Great Britain (built by Birmingham Electric Furnaces Limited, who are now building a second one), whilst it is the most usual type in the United States.

Fig. 1.—Two counterflow carburising furnaces.

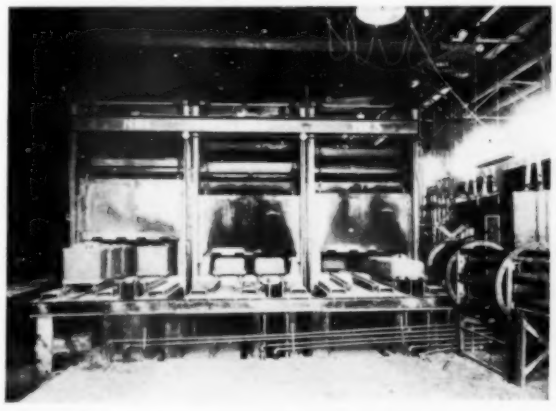


Fig. 2.—540 kw. three-chamber counterflow carburising furnace, Note inverter on right.

A typical installation of two counterflow carburising furnaces is illustrated in Fig. 1. One of these furnaces is rated at 150 kw., and the other at 160 kw. Each furnace takes two rows of carburising boxes and alloy trays. These rows travel in opposite directions, boxes being charged and discharged at both ends. Three rectangular, or two round boxes are loaded on each tray, the boxes being made of welded sheet metal. The furnaces are 66 ft. long, the end portions serving as heat-exchange chambers, whilst the centre portion is electrically heated in three zones. The temperature is very accurately controlled, the limits being plus or minus 5° F. The tracks through the furnaces are equipped with rollers, the charge being propelled by

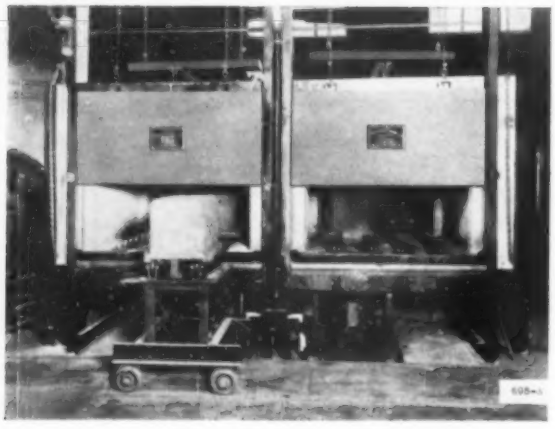


Fig. 3.—Front end of 180 kw. two-chamber return flow recuperative carburising furnace.

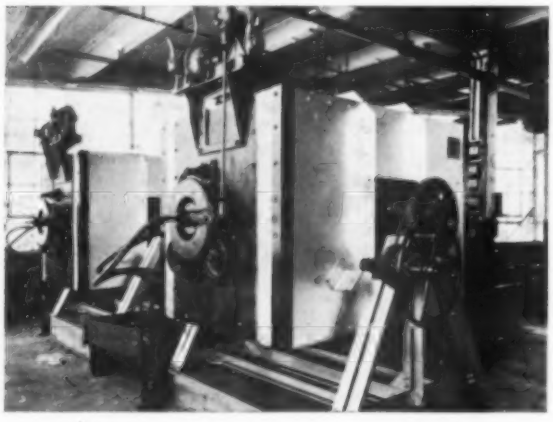
hydraulically-operated mechanism, the pushing mechanism operating automatically at the proper intervals.

Fig. 2 shows one end of a large three-chamber furnace of 540 kw. capacity. As is usual with these continuous furnaces, alloy sheet metal boxes are used with cast alloy trays. The boxes are packed with the charge and compound, covered with an alloy tray, then inverted by means of the reverser shown on the right-hand side of the photograph, and passed through the furnace in this position. With this method no luting is required, and there is a considerable saving in the weight of the containers.

An important advantage of the counterflow furnace is that it permits the use of light sheet-metal boxes. With the batch-type furnace such boxes are not very successful, owing to the tendency to distort with the quick heating and cooling, but under the conditions in the recuperative furnace, where the heating and cooling are gradual, the life of these containers is very good.

The Electric Furnace Co., of U.S.A., have also built a number of return-flow recuperative furnaces for carburising, similar to those shown in Part I. on annealing. Fig. 3 illustrates the front end of a double-chamber furnace of this type. In each chamber the carburising pots are pushed down one row, transferred across, and returned along the other row to the same end, all the charging and discharging thus being done at one end of the furnace. This arrangement is very often much more adaptable to the general flow of material through the plant. The general arrangement, and the absence of any possibility of through-draught, makes this type of furnace very efficient. Another advantage it may have over the straight-through recuperative type is that it can be efficiently made in units half the size. The consumption of electrical energy with counterflow furnaces is approximately 1 k.w.h. per 12 lb. of gross load.

Fig. 4.—Back view of two 60 kw. rotating retort carburising furnaces.



Rotary Retort Carburising.

Whilst it is necessary to carburise most parts by this method of packing in boxes, certain small parts may be carburised by a simpler and more economical method. In this method the charge is put into a retort, together with a small quantity of carburising compound. The retort is heated and rotated for a given period, after which the charge is emptied out. As the retort forms part of the furnace, only the charge and the small amount of compound has to be heated each time, and a considerable saving is effected. Owing to the stirring action, the time of carburising is reduced compared with the other methods.

This method of carburising has been used in fuel-fired furnaces. As, however, recuperation is not possible with small tilting units of this type, the fuel-fired furnace is necessarily inefficient and the electric furnace has a greater advantage in running costs compared with the usual methods. The economy of this method is due to the fact that there is little to heat other than the charge, the time taken is reduced, and the labour of packing eliminated. Against this is the fact that the heat in the charge is entirely lost, and that it is only suitable for small articles which cannot be damaged by the slow rotation of the retort. A rear view of two furnaces of this type is given in Fig. 4.

Reheating and Hardening.

PUSHER TYPE HARDENING AND TEMPERING INSTALLATION.

A great number of furnaces have been designed for special hardening operations, but only a few examples can now be given. In many cases the hardening furnace and quenching tank are combined with a low-temperature tempering

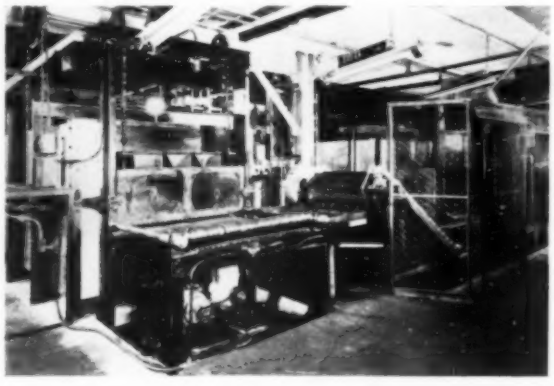


Fig. 5.—Installation of hardening and tempering pusher-type furnaces, showing entrance end of 150-kw. tempering furnaces.

furnace. An interesting example of this is illustrated in Fig. 5. This unit consists of a continuous pusher type 220 k.w. hardening furnace, quenching tank, conveyor, and 150 k.w. tempering furnace. This installation is for heat-treating rear axle shafts, and in this instance the shafts are passed through the respective furnaces lengthwise, and not across the furnace as is more usual. Each furnace is 20 ft. long and 52 in. wide inside, and the installation has a capacity of 2,000 lb. of shafts per hour. The attendant places the shaft in grooves outside the furnace, and they are automatically pushed forward a shaft length at a time. The shafts are actually pushed in turn, and not simultaneously. At the other end, the axles are automatically discharged down an incline into an oil-quenching tank without coming into contact with the atmosphere. From here they are conveyed to a loading and draining platform and pushed lengthwise through the tempering furnace. The photograph shows the charging end of the tempering furnace. The two furnaces are side by side, so that the discharge end of the tempering furnace is next to the loading end of the hardening furnace.

Pusher-type furnaces are very commonly used in the heat-treatment of steel. Besides their use for comparatively large parts, they are commonly used for small parts, such as gudgeon pins, rollers, bearings, etc.

Rotary Hearth Furnace.

Fig. 6 illustrates a 110-kw. rotary hearth furnace, together with electric cyanide pot, which is used for the treatment of transmission gears. In certain cases where the treatment is lengthy some decarburisation of the surface may take place. For this reason the gears after removal from the furnace are placed in the cyanide pot for 1 min., and then quenched in oil. This short immersion in cyanide serves to replace any carbon lost from the surface. Rotary hearth furnaces are used for many other purposes, including the heat-treatment of nuts and bolts, ball-bearing parts, etc. In many of these cases the charge is placed in pans, and the furnace provided with automatic means for tilting the pans and dropping the contents into the quench.

Double-deck Roller Hearth Furnace.

A totally different type of reheating furnace is illustrated in Figs. 7 and 8. These furnaces are specifically designed for the heating of crown wheels prior to oil-quenching in presses. Very often rotary hearth furnaces are used for this purpose, having the advantage that one operator can charge and discharge, and, moreover, the furnace may be used for other types of gears. This type of roller hearth furnace has the advantage of being able to deal with very large outputs in a small space, there being two tiers of rollers, as will be clearly seen from the photograph.

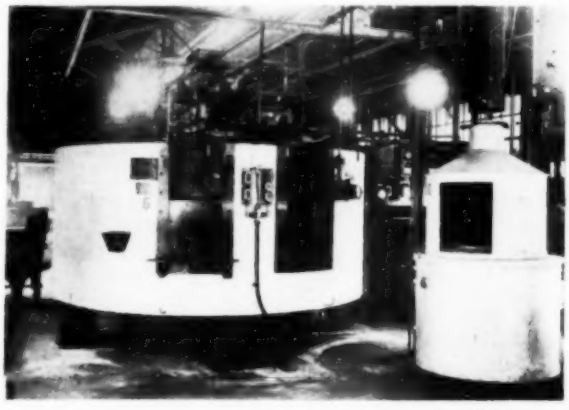


Fig. 6.—110 kw. rotary hearth furnace with 25 kw. cyanide pot.

The ring gears are placed on these rollers, which, being automatically rotated, carry them through the furnace to the discharge end. Actually, there are two entirely distinct chambers, each having two heating zones—the first to bring the gears up to the required temperature, and the second zone to provide the requisite soaking period at a constant temperature. The furnaces illustrated are rated at 120 kw. each, and are 24 in. wide × 13 ft. long inside.

Belt Conveyer Furnace.

A very useful type of furnace for the hardening of small parts is the belt-conveyer furnace. Various types of belts have been developed for this purpose, but many of these suffer the disadvantage of stretching and short life, especially when used in large-sized furnaces. A very successful belt for large sizes has been developed by the Electric Furnace Co., of Salem. This belt is built up of specially designed cast alloy links, so shaped that a continuous surface is formed, and even quite small parts cannot fall through the joints.

In this design the belt never leaves the furnace, but returns inside the chamber. At each end the belt runs over an alloy drum, the drum at the charging end being arranged to take up automatically the expansion of the belt due to temperature changes. It should be added that the belt itself is flexible, no bending of the actual material taking place. At the charging end the material may be placed on the belt through a door at the end of the furnace, as in Fig. 9, or the end of the furnace may be so shaped that the material may be charged directly on to the surface of the belt, an example of this type being shown in Fig. 10. In most cases the parts are allowed to drop from the belt through a sealed chute into the quenching tank, and usually means are provided for the continuous removal of material from the quench by means of a conveyer. In certain cases where it is undesirable to allow the objects to drop into the quench, or where the quenching must be done in a special jig or press, a side door is provided through which the material may be removed. An example of this method is shown in Fig. 9, where the operator is removing gears from a side door and quenching them in a special machine. In most cases the side door is additional to the drop-quench method, so that either type of material may be treated in the same furnace. These conveyer furnaces are especially adapted to handling bolts, nuts, rivets, ball- and roller-bearing races, small gears, miscellaneous forgings, chain sprockets, springs, and many other small and medium-sized products. Extremely uniform treatment is obtained, and no pans or trays are used, so that the efficiency is very high.

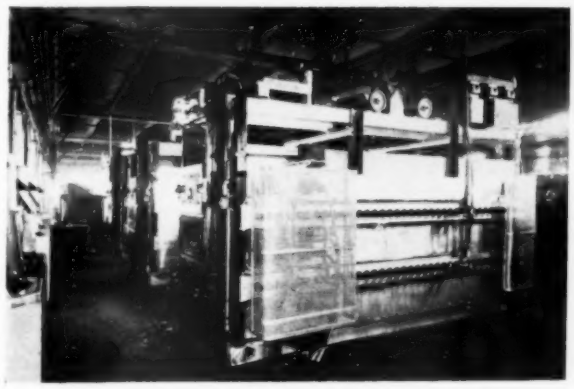


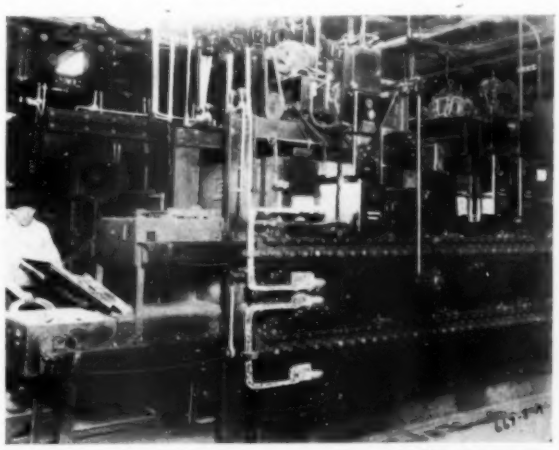
Fig. 7.—Battery of three 120 kw. driven roller hearth furnaces.

In all cases, variable speed gear is fitted so that the period of treatment may readily be varied to suit the material. The furnace illustrated in Fig. 9 is rated at 110 kw., and is used for different types of gears, the period of treatment ranging from 30 to 90 mins., and the output from 500 lb. to 800 lb. per hour. The furnace illustrated in Fig. 10 is rated at 190 kw., and can deal with 1,600 lb. of material per hour.

Tempering.

Tempering may be carried out in a number of ways. Lead, oil, or salt baths are commonly used, and air ovens fitted with circulating fans are rapidly coming into use. All these types have been adapted to continuous operation.

Fig. 8.—Charging end of roller hearth furnace.



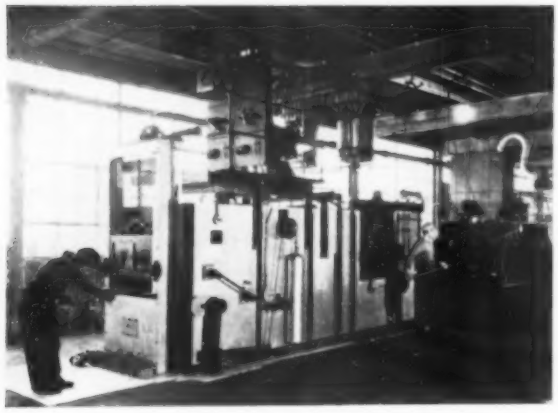


Fig. 9.—110 kw. belt conveyer furnace for hardening gears.

In many cases where the tempering temperature is high, continuous furnaces, very similar to the hardening furnaces, are used. One of these was illustrated in Fig. 5, and in the treatment of nuts and bolts, springs, etc., a chain-belt tempering furnace very commonly follows a similar hardening furnace.

Fig. 11 illustrates a continuous salt-bath furnace. This furnace is 20 ft. long, 4 ft. wide, and 4 ft. deep. By means of a propeller, the molten salt is continuously circulated in a definite path. The temperature of operation in this case is about 210° C., at which temperature there is no fuming. Although the salt is very much more expensive than oil, the running cost is less, as it does not adhere to the work as the oil does, and, moreover, does not suffer from the disadvantage of oxidation, etc. Over this tank is provided a continuous chain conveyer, arranged so that the hooks on the conveyer reach the surface of the liquid, the suspended parts being fully submerged. The capacity of this furnace (which is rated at 75 kw.) is 3,000 lb. per hour.

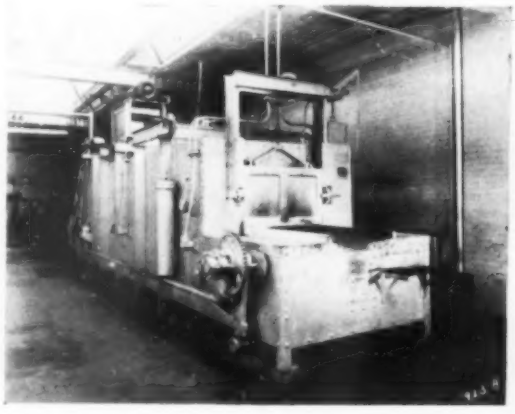


Fig. 10.—190 kw. belt conveyer furnace for hardening roller bearing races.

Nitriding.

Many different types of nitriding furnaces have been built, but the one illustrated in Fig. 12 is of especial interest, in being the largest nitriding furnace so far installed. This furnace is designed for nitriding large parts, such as crankshafts, piston pins, pistons, large machine parts, etc. It is rated at 600 kw., and has a heating chamber 24 ft. long × 5 ft. 9 in. wide × 5 ft. 6 in. high. The nitriding box is 22 ft. long by approximately 3 ft. wide and 2 ft. 6 in. high, special means being provided to make a gas-tight joint between the lid and the pot. A fan is provided at the end of the box, so arranged that there is a continuous circulation of ammonia through all parts. A full charge weighs about 8,000 lb. To ensure even distribution of the ammonia it is admitted at five points along the box. Special plant is provided for supplying the ammonia, and for measuring the amount of dissociation. One of the characteristics of the electric furnace is its adaptability. Furnaces can be designed to deal with almost any special operation required, and whilst there are very many examples of these special types, in most cases the furnaces are much smaller than those which have just been described.

Owing to the large scale of production in the United States, there have undoubtedly been more opportunities for installing large continuous production furnaces than in this country. At the same time, there is a growing demand for such furnaces on this side, and as the advantages are more fully realised, so will the demand further increase. In comparing conditions in this country with those in the States, it should be remembered that many of the electric furnaces which have been described in this article are installed in districts where natural gas, having a calorific value of 1,100 B.th.u.'s can be obtained at less than 50 cents per 1,000 cub. ft.—a price equivalent to less than 10d. per 1,000 cub. ft. of ordinary town gas (£ at par), whilst electrical energy is no cheaper than in industrial districts on this side. Under these conditions the direct energy costs are far greater with electricity than with natural gas, but the total over-all cost is less with electricity, owing to the uniformly high quality of products obtained, and the elimination of the human factor.

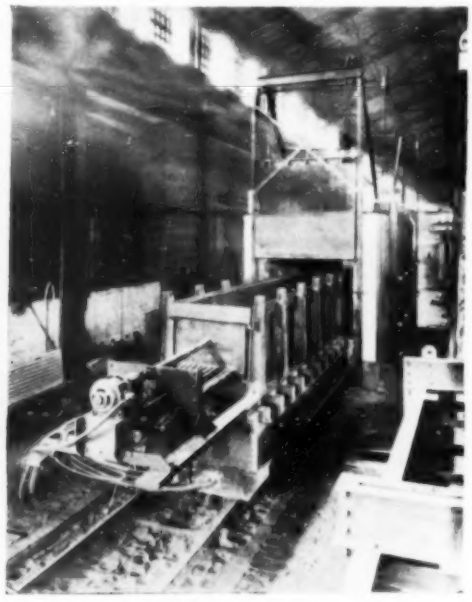


Fig. 12.—Large nitriding furnace, rating 600 kw., length 24 ft.

Fig. 11.—75 kw. continuous salt bath.

It is hoped that this short account of some installations in the United States will help users on this side to realise the extent to which electric heating has been developed in that country. It cannot be too strongly emphasised, as stated above, that this rapid development has not been fostered by any advantage in the price of electricity as compared with various fuels (as is commonly assumed), but simply and solely because electric heating has usually been proved to be the cheapest when every factor is taken into consideration.

Creep of Metals

An Accelerated Test for the Determination of the Limiting Creep Stress of Metals.

THE engineer has made considerable advances into the high-temperature field, but the limit of the advantages to be gained in this direction has not yet been reached. Future developments will, however, depend largely on the supply of suitable data which can be used for the purposes of design, as well as improved heat-resisting materials at an economical cost. The nature of data required for the correct design of plant to be used at elevated temperatures is now appreciated, and tests usually take the form of determining for each temperature the relationship between the applied stress and the rate of creep, so that the stress causing any desired rate of creep may be extrapolated. Considerable thought and time have been expended during the last few years in developing new forms of accelerated creep tests intended to produce in a short time the same indications regarding the fitness of material as must occupy very long periods when tests are made by the more fundamental long-duration method. Among such methods is that devised by Messrs. W. Barr and W. E. Bardgett, who discussed their method in a paper at the recent annual meeting of the Institution of Mechanical Engineers.

The method depends on the accurate measurement of the diminishing rate of creep in a specimen initially subjected to a maximum commencing load, measured by means of a steel weigh-bar, so that the rate of decrease of the applied stress is proportional to the extension of the heated test specimen. In this form of accelerated test the novel procedure adopted eliminates searching, and enables the stress value to be obtained in a period of 48 hours. Simplicity of apparatus and ease of manipulation have been aimed at, and the test offers many advantages in this respect.

A diagram of this apparatus is shown in Fig. 1. A test-piece 6 in. long and 0·25 in. diameter is heated by means of a resistance-wound furnace 24 in. long, the winding of which is made close at each end of the tube, so that the variation of temperature along the test-piece does not exceed 2° C. The temperature is controlled to within ± 0·5° C. by means of a McLaren thermostat located in the winding of the furnace. This type of thermostat operates on the principle of the difference in expansion between a silica rod and an outer nickel-chromium casing, the total current being switched off and on at approximately regular intervals. In order to obtain the required limits of temperature control under these conditions, it was found necessary to introduce a thick metal sleeve between the test-piece and the furnace wall. The sleeve is made from a bar of non-scaling steel about 12 in. long, having a hole drilled through the centre large enough to allow the test-piece to enter. This arrangement efficiently damps the slight temperature oscillations due to the action of the thermostat.

The extension of the weigh-bar is measured by means of an extensometer consisting of an Ames dial gauge in conjunction with a simple lever device. The weigh-bar and extensometer are accurately calibrated in a tensile testing machine. One division of the dial is equal to a stress of 0·006 ton approximately, and since readings can be taken to one-quarter of a dial division, this is equivalent to 0·0015 ton approximately. It has been determined experimentally that the extension of the test-piece corresponding to this value of stress decrease is 7×10^{-6} in. per inch approximately.

Stress is applied by turning the screw C, Fig. 1, and the actual stress on the test-piece is known from the extension of the weigh-bar. Should any creep take place in the test-piece, this is immediately indicated by a decrease in stress, as shown by the extensometer. Consider a test-piece stressed to 14 tons per sq. in.—say, at 500° C., well within the creep range: the test-piece creeps fairly rapidly at first, and there is correspondingly rapid decrease in stress. As the stress decreases, the rate of creep diminishes, and a curve of the form shown in Fig. 2 is obtained. If a new test-piece is stressed, at the same temperature, to the

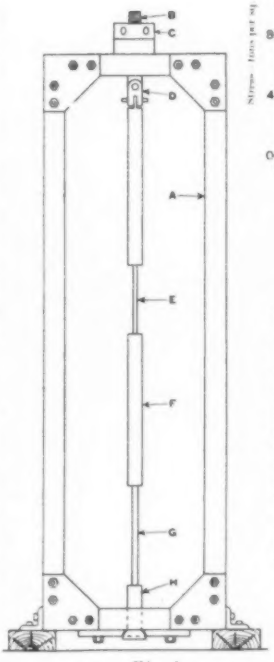


Fig. 1.

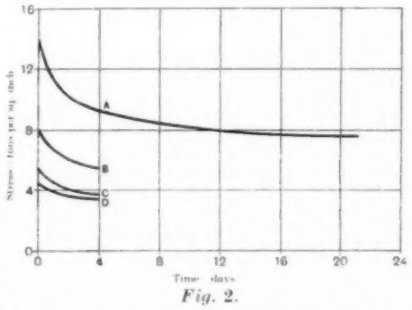


Fig. 2.

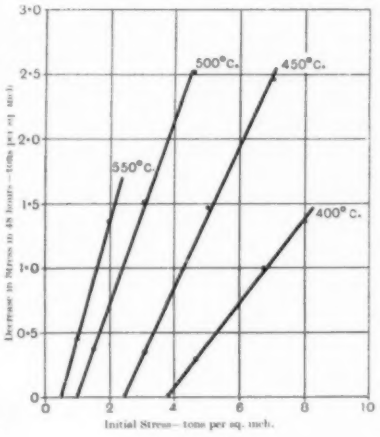


Fig. 3.

remanent stress of the preceding test, it is found that it shows an initial rapid decrease in stress, which, however, takes place at a lesser rate than the initial stress decrease in the preceding test (see Curve B, Fig. 2). Curves C and D at still lower initial stresses show a decrease in stress, but at a correspondingly decreasing rate.

After carrying out a preliminary series of tests along these lines, it was found that the initial stress was approximately proportional to the decrease in stress in a given time. Hence, by plotting the decrease in stress against the initial stress, the straight line drawn through the points it produced cuts the initial stress axis at a certain value, representing the stress which will give no measurable decrease in stress in the period of the test. As previously explained, this must correspond to the total creep of less than 7×10^{-6} in. per inch for the period of test.

After numerous experiments, it was found that a period of 48 hours gave the best combination of accuracy and limited-test duration, consequently this period was standardised for all tests. On this basis the rate of creep will be less than $1 \cdot 45 \times 10^{-7}$ in. per inch per hour approximately. Since this rate of creep is likely to be very much greater than the average rate over extended periods, there are obviously great practical advantages in being able to estimate accurately and rapidly the probable limiting creep stresses corresponding to such a low rate of creep.

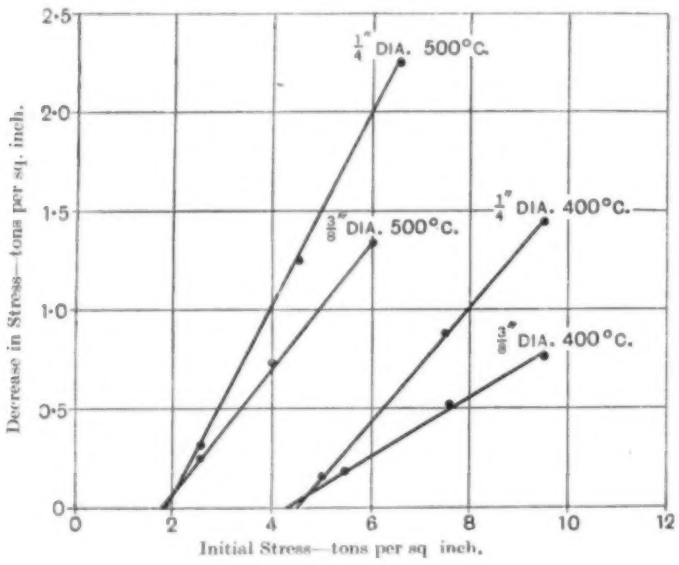


Fig. 4.

A series of initial stress-decrease in stress curves obtained for a 0·11% carbon steel at various temperatures is shown in Fig. 3, from which it will be observed that the rate of decrease in stress as indicated by the slope of the curves increased with the temperature. This is due to the diminishing influence of strain-hardening on the rate of creep as the temperature rises. From the nature of this test it will be understood that for any given conditions of temperature and initial stress the rate of decrease in stress (in tons per sq. in.) will depend upon the dimensions of the test-piece. In order to determine the influence of this factor on the results obtained, comparative tests were carried out at temperatures of 400° and 500° C., using test-pieces 6 in. long by ⅜ in. and ¼ in. diameter respectively. All the test-pieces were cut from the same bar of steel (0·23% carbon, 1·67% manganese), and were all in the fully annealed condition. It was found that the limiting creep stress values obtained (Table 1) agreed to within fairly close limits at each temperature, any variation being within the range of experimental error.

TABLE I.

Diameter of Test-piece in Inches.	Limiting Creep Stress, Tons, per Sq. In.	
	400° C.	500° C.
¼	4·5	1·8
⅜	4·2	1·7

TABLE II.

RELATIVE EXTENSIONS OF ¼ IN. AND ⅜ IN. DIAMETER TEST-PIECES AT 400° C.

Diameter of Test-piece, In.	Initial Stress, Tons per Sq. In.	Extensometer Reading, Divisions	Final Stress, Tons per Sq. In.	Extensometer Reading, Divisions	Decrease in Stress, Tons per Sq. In.	Extensometer Reading, Divisions
⅜	9·5	73·0	8·04	61·75	1·47	11·25
¼	9·5	163·75	8·71	150·25	0·79	13·5

Referring to the curves obtained in the above tests, Fig. 4, it will be observed that although the two curves for any one temperature cut the initial stress axis at practically the same point, the slope of the curves is different, being greater for the ¼-in. diameter test-piece. The reason for this is made clear from the data given in Table II. The ⅜-in. diameter test-piece has to extend farther than the ¼-in. diameter test-piece for a given decrease in stress. Similar reasoning will show that for test-pieces of the same diameter and different lengths, the rate of decrease in stress will be greater, the longer the test-piece.

The straight-line relationship between initial stress and stress decrease necessitates the determination of only two points on the curve, but a third point is recommended as a check. To save time, three test units are run simultaneously at the same temperature. The test-pieces are heated to the required temperature, which is measured to the nearest 0·1° C. by means of a potentiometer. Before the application of stress, the whole apparatus is allowed to adjust itself to the prevailing internal and external thermal conditions. This usually requires several hours. A different initial stress is then applied to each test-piece. No further observations are necessary until the end of the 48-hour period, when the remanent stress on each test-piece is determined. The temperature of the test-pieces is recorded on a thermograph during the course of the test, and it is essential that all temperatures, including that of the room, be at their exact original value when the final stress values are observed.

FORMATION OF MARTENSITE IN HIGH-CARBON STEEL.

The formation of martensite in high-carbon steel has been studied by H. Hanemann and H. J. Wiester, who present the test results in the January issue of *Archiv für das Eisenhüttenwesen*. The steel samples were quenched from above the A_1 point in fusible alloys kept at definite temperatures, and tested under the microscope on the appearance of the first dark-coloured martensite needles in the homogeneous austenite. The temperature at which the martensite formation begins is dependent on the carbon content, as can be seen from the following table :—

Composition of Steel.					Temperature at which Martensite Formation Begins, ° C.
C.	Si.	Mn.	P.	S.	
1·69	0·14	0·45	0·017	0·020	80
1·60	0·51	0·27	0·027	0·037	90
1·52	0·12	0·50	0·040	0·010	100
1·40	0·43	0·24	0·022	0·040	110
1·35	0·11	0·21	0·031	0·008	130
1·27	0·13	0·60	0·022	0·022	150
1·17	0·21	0·34	0·026	0·014	180
1·06	0·22	0·34	0·026	0·016	200
0·96	0·21	0·33	0·031	0·017	220
0·90	0·17	0·37	0·016	—	230
0·83	0·17	0·30	0·027	0·024	240

The austenite-martensite transformation is practically independent of the cooling rate, and continues even at very low temperatures. At each temperature a well-defined equilibrium between the two constituents exists. Between 250° C. and the temperature of the beginning martensite formation, the austenite is very stable. At higher temperatures it decomposes into ferrite and cementite.

METALLURGIA

The British Journal of Metals

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Subscription Rates throughout the World - - 24 - per annum, Post free.

Published Monthly by the Proprietors, THE KENNEDY PRESS LIMITED, at 21, Albion Street, Gaythorn, Manchester.

Telegrams: "Kenpred," Manchester. *Telephone: Central 0098.*

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

The Application of Research to Industry.

THROUGHOUT the ages, civilisation has been dependent upon research for increasing knowledge by revealing the secrets of the world and that which is found in it. No hit-or-miss method would have sufficed to establish the degree of progress that now exists. It is the results of research that have shown everything in the world to be possessed of special potentialities of which mankind can avail itself when the need arises. It is, of course, true that one age may be more successful than another in adding to the store of knowledge or in making full use of that which exists, but the totality of the knowledge of the world is ever on the increase.

Progress has been so great during the last hundred years that there are few who question the indirect value of research, but there are many who still retain the opinion that there is only a remote connection between research and industry. Yet the results of research have caused the development and exploitation of such discoveries as fire, corn, ships, metals, steam, electricity, etc., for the benefit of mankind. It is sometimes forgotten that research is another form of pioneer work, and subsequent development is frequently slow because of the continued need of further research. Discoverers of new lands were able to give very little information about their discoveries. In many cases the extent of the discoveries and an approximation of their potentialities were not appreciated for years afterwards, and then only after pioneers had prepared the way for more general development by further investigation. In a similar way, research constitutes the framework that gives fundamental support to the continued development of industry. Thus, primarily, the research worker is a pioneer following up discoveries and investigating them with the object of ascertaining facts; in this way, new problems are continually being presented to research workers, and the results of their investigations provide the knowledge which can be applied to industry.

This application of the results of research is frequently very slow. There are many reasons for this apparently conservative spirit that is invariably associated with industry, and the Minister of Transport, Mr. P. J. Pybus, made a suggestion likely to facilitate the application of research to industry, at the annual dinner of the Institute of Metals. He suggested that the results of research should be summarised in such a way that they can be grasped by men in the shops. He, of course, implied that metallurgists employ technical language that is understood by scientists but is not readily understood by men in the shops, and therefore cannot be absorbed by them. Metallurgists are, of course, similar to members of other trades and professions in this respect. Medical men, architects, engineers, foundrymen, fitters, to mention only a few, all have their own technical language, which is perfectly well understood within their own ranks, but is not easily grasped by the layman. But would a summary in non-technical language suffice to speed up in the workshop the application of some research? We doubt it, because technical knowledge will still be necessary to apply the information, particularly in regard to metallurgy. When applied to foremen, managers, and those holding executive positions in works, the suggestion is valuable, as such a summary would enable them to grasp the significance of a particular research and would cause them to investigate further if the summarised version appeared likely to be profitable in application.

Much fundamental research has been carried out in purely scientific laboratories, and the advantages of pure research to improve our knowledge of the properties of metals cannot be overestimated, but there is a similar need for the practical metallurgist as a connecting link between fundamental research and industry. Many forms of research involve a considerable number of investigations and repeated trials before they can become absorbed in normal production, and this retards application. So many conditions must be satisfactorily met before a manufacturer will be prepared to change his material, modify his product, or use tools different from those his men have become expert in the use of over a long period. Invariably such a change increases the working costs and reduces output, at least for a time, and one cannot wonder that the manufacturer desires to be fully convinced that a change will be worth while before it is made.

Considerable attention has been given to this problem of the application of research to industry, and in his presidential address at the recent annual meeting of the Institute of Metals, Sir Henry Fowler referred to the work the Institute has done and is doing, which is contributing largely to a better understanding between the scientific and the so-called practical man. That there is considerable progress in this direction few will deny, and there can be no doubt that the increased facilities for metallurgical training as well as the growing importance of metallurgy generally, has helped to bring this about.

It is now appreciated that works executives have a better technical education than formerly, and while every effort should be made to provide lucid information respecting any development resulting from research, so that it can be readily absorbed, its assimilation in industry will necessarily be slow, because a variation in technique from that which has been customary is frequently involved. It is only necessary here to cite one of many examples. For instance, consider tungsten carbide-tipped tools, the properties of which are so familiar, yet opinions differ respecting the advantages claimed for them in their application. Many factors must be taken into account when introducing a new method, process, or development, and the conditions that would be ideal for one material may result in utter failure with a new material.

The value of research to industry in the past has been of a high order, and there can be no doubt that both now and in the future even more valuable work will be accomplished, and the question whether industry will be able to apply it rapidly will depend upon whether industry is ready to absorb it. It must be so, because in some instances the needs of industry are in advance of research, whereas in others research is in advance of industry. In the former instances the applications are known, and new developments are readily grasped and given practical tests almost at once, to discover the extent to which they meet demands and also to overcome difficulties that may be encountered in practice. When research is in advance of industry, and no direct application seems to present itself, there is a danger that the work may be overlooked. Some of the metallurgical researches of Faraday, for instance, were well in advance of industrial requirements, and valuable results were not absorbed by industry until many years afterwards, when other investigators explored the possibilities of alloy steels.

Every effort should be made to broadcast intelligible information concerning the results of research, and research workers as well as so-called practical workers should be constantly searching to provide applications, for just as we apply new ideas to the advancement of civilisation, so shall we as a nation remain in the vanguard of progress.

Fatigue of Metals.

Although much research work has been devoted to the subject of fatigue, erroneous ideas prevail in regard to the meaning of the term in its application to structural materials. Probably this is due to the fact that the term is somewhat misleading and implies that the material has become tired—that a condition of fatigue or tiredness exists prior to the development of a crack and subsequent facture. Despite the work of many investigators who have established the fact that no crystal growth takes place in steel, and that the term is used to describe the circumstances causing a type of fracture brought about by repeatedly overstraining material which is a component part of some structure intended to give long service, a further searching inquiry into the subject has been made. A Committee, appointed by the North-East Coast Institution of Engineers and Shipbuilders some time ago, has investigated the subject, and a Report has recently been issued. The Committee has restricted its attention to materials with which its members are more immediately concerned, and this naturally tends to localise the application of the term within narrow limits, whereas it is applied in a much wider field. It is of interest, however, that a body of engineers should find it necessary to hold an inquiry, and although no new theory has been suggested, the Report should prove valuable in removing erroneous opinions held by many engineers; the subject however is of such interest in its wider application that the Report will undoubtedly lead to further discussions, and the ultimate results will certainly justify the work of the Committee.

Limitatious of our Fundamental Knowledge of the Properties of Metals.

Let us standardise materials and processes, but be very careful not to standardise our minds, said the president of the American Society of Testing Materials, Mr. F. O. Clements, at a joint meeting of A.S.T.M. members in the New York Metropolitan District and other technical societies, recently. Standardisation must always go forward without building fences to prevent developments or block future progress. He spoke on the limitations of our fundamental knowledge of the properties of metals, and referred to the seemingly limitless energy of nature, much of which is invisible to our physical senses: what can be seen is infinitesimal compared to the vast world of unknown and unexplored territory all around us. Discussing the 92 elements in the periodic table, he asserted that there are many relations in these periodic tables of whose precise significance we are still ignorant.

The stupendous task of even calculating the number of alloys that night be produced from all the varying combinations of the 64 elements regarded as metals, makes one realise that "rule-of-thumb" methods are frightfully inefficient in searching for alloys having special properties. We need a knowledge of how atoms and molecules of metals arrange themselves when alloyed together, and how each arrangement affects physical properties. When this field is properly understood, said Mr. Clements, it will be possible to predict from any combination of metals what the properties of the alloys will be, and, conversely, given a set of physical properties, the alloy having these properties can be calculated. As an example of the accuracy necessary in alloying for specific properties, reference was made to the nickel-iron alloy "Permalloy." This alloy brought about revolutionary changes in submarine cable construction and operation. The highest permeability occurs when the composition of the alloy is nickel 78·5% and iron 21·5%. Slight differences in composition destroy the value of the material for the purpose intended. How easily those responsible for this outstanding bit of research could have missed the object desired. This example of a simple binary compound shows that untold numbers of alloying combinations are possible. Examples of many specifications of steel were cited in which the manganese content was limited between 0·30 and 0·60%. Other identical steels with one change, the manganese between 0·60 and 0·90%, are radically different materials requiring changes in heat-treatment to secure the desired properties. The phenomena which accompany the hardening of steel by quenching are still the subject of much discussion and debate.

Small amounts of various metals are necessary to the health of the human body and the proper functioning of different glands, but that is about all that we know. There is a tendency to think that so much information has been acquired in regard to materials that little more remains to be done. This is said because fundamental knowledge is lacking. It is the nation that takes the longest view and realises most clearly the value of deepening knowledge of fundamental problems that will reap, in the future, the fruits of great achievement.

The unsolved problems pertaining to metals are innumerable, and Mr. Clement referred to certain fundamental data that the industrial world needs in the hope that they would stimulate action in course of time.

Forthcoming Meetings

THE INSTITUTION OF MECHANICAL ENGINEERS.

Mar. 18. "The Machinability of Steel as Indicated by its Macrostructure," by F. E. Robinson, M.I.Mech.E., and C. T. Nesbitt.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

April 15. Presentation of Diploma of Hon. Fellowship to Mr. Summers Hunter, C.B.E., *Past President.* Informal Discussion on the rejuvenation of ships and their machinery, to be opened by Andrew Hamilton, C.B.E., *Member.*

THE INSTITUTE OF MARINE ENGINEERS.

Mar. 31. "The Salvage of Ex-German War Vessels at Scapa Flow," by E. F. Cox, in the lecture hall of the Institute, The Minories, London, E.C. 3.

INSTITUTE OF METALS.

Birmingham Section.

Mar. 17. "The Extrusion of Metals," by R. Genders, M.B.E., M.Met.

London Section.

Mar. 17. "The Efficacy of Testing Methods," by H. J. Gough, M.B.E., D.Sc., Ph.D.

April 14. Annual General Meeting and Open Discussion.

North-east Coast Section.

Mar. 15. "Refining of Copper," by R. D. Burn, M.Sc. Annual General Meeting.

INSTITUTE OF BRITISH FOUNDRYMEN.

Birmingham Branch.

April 7. Annual General Meeting. General Discussion.

East Midlands Branch.

April 2. Annual General Meeting. Short paper competition (at Loughborough).

April 9. Lincolnshire Section. Annual General Meeting Open discussion on Foundry Problems.

Lancashire Branch.

April 2. Annual General Meeting. "General Rotary Furnace Practice," by W. Scott.

Middlesbrough Branch.

April 8. Annual General Meeting. Cinematograph Film. General Discussion.

Newcastle-on-Tyne and District Branch.

Mar. 26. "A Few Hours on the Floor of a Jobbing Foundry," by A. Suteliffe.

Sheffield and District Branch.

Mar. 18. "Notes on Steel Foundry Practice," by C. D. Pollard.

April 15. Annual General Meeting. "The Spun Pipe Plant of the Staveley Coal and Iron Co.," by J. B. Allan.

Wales and Monmouth Branch.

Mar. 19. Annual General Meeting.

West Riding of Yorkshire Branch.

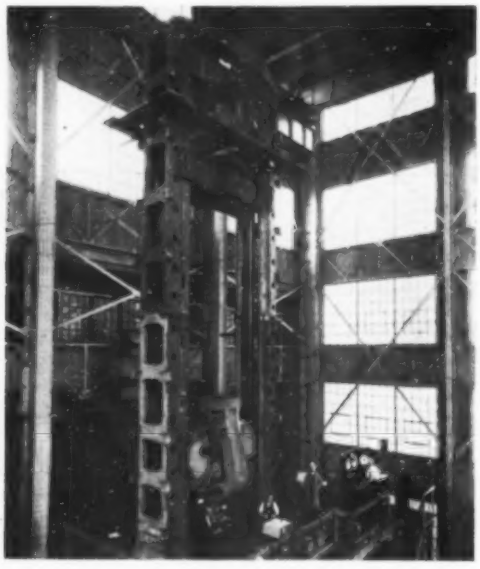
April 9. "Some Aspects of Steel Founding," by H. Forrest.

April 30. Annual General Meeting.

Testing Machine of Unusual Capacity.

THERE has just been completed in the shops of Baldwin-Southwark Corporation, Eddystone, Pennsylvania, a very large testing machine. It is able to test columns up to 33 ft. 6 in. long in compression up to 4,000,000 lb. load. In tension it will take specimens up to 33 ft. 6 in., and will apply loads up to 3,000,000 lb. The spread between the columns is 10 ft., and the table is 12 ft. long. Since the table is level with the laboratory floor, a truck may drive between the columns and the specimen be lifted directly from the truck body by the testing machine itself.

The principal load application is hydraulic, and the ram used in the cylinder is 46 in. in diameter, the hydraulic pressure being about 2,500 lb. per sq. in. when operating at capacity. The table of the testing machine is stationary, being secured directly to the foundations. The ram is fastened to this table. The cylinder, therefore, is the movable element, and to it is fastened by lug extensions two vanadium steel screws 12 in. diameter, 56 ft. 8 in. long, threaded double one-third square threads per inch. By means of long bronze nuts which are bedded in the lower cross-head (which carries also the weighing system and, in a yoke, the lower grips for tension testing) the loads are



A remarkable testing machine of large capacity.

transmitted from the screws to the cross-head. The purpose of the threads, however, is not to produce the load as has been the practice in some types of testing machines. During loading there is no movement of nut and screw relative to one another. The function of the screw and nut is to raise or lower the lower cross-head, so that the space available for testing may be changed to accommodate the specimen to be tested.

Compression tests are carried out between the lower cross-head and the table, while tension tests are made between the upper cross-head and the yoke around lower cross-head. The total stroke of the lower cross-head (load stroke and not movement on the screws) is 48 in.—ample for the extension of practically any tension specimen capable of being tested in this machine. The total adjustment for change of specimen length is 33 ft. 6 in. This latter change is effected by rotation of the screws by means of a geared motor controlled from the control board, which is located at some distance from the machine, communication between the operator in the control room and the operator at the machine being had by telephone.

In both compression and tension testing the lower cross-head moves downwards. In order that these heavy-weights—about 200,000 lb.—may be returned to position preparatory for a new test, it is necessary to provide two 13 in. diameter pull-back cylinders, which are supplied with pressure from the same source as that for the main cylinder and ram. These pull-back cylinders have another very important function to perform. In the failure of specimens either in tension or in compression, there is an enormous store of energy released in a very small fraction of a second. These cylinders and rams, together with four nests of heavy springs absorb this "shot" of free energy and damp it out without damage to the structure, acting like gun-recoil chambers.

The weighing system is the Emery support or hydraulic capsule, and not by measurement of the pressure in the main ram. In the path of the forces coming from the main ram to the specimen is the hydraulic capsule. This is a very heavy inelastic cylinder having a loose-fitting piston, the end of which is covered by a diaphragm. The movement of this ram is of the order of a few thousandths inch at most, and the oil (with which the capsule is filled) displaced by this micrometer motion causes a change of shape of the elastic tubes (with which the capsule is connected) in the indicating instruments, of which there are four on the instrument board. The ranges of these indicating instruments are: 0 to 4,000,000; 0 to 2,000,000; 0 to 525,000, and 0 to 200,000 lb. The calibration of this machine required the services of three men—all experts—for one week.

One of the unusual and unique features of this machine which will be installed shortly in the laboratory of the University of California, at Berkely, California, is the highly refined control which is incorporated. Devices are mounted for maintenance of constant load over an indefinite period, devices for application of load at constant rate of load increment, start, stop, and inching buttons for motor control: limit switches for safety and cut-outs for same under specific conditions. A Telechron clock and indirect lighting for the gauges as well as pilot lights for motor circuits are unusual refinements.

The Importation of Tin by the United States.

The value of tin required by the United States is much greater than that of any other mineral product that is furnished almost entirely by importation, points out the United States Bureau of Mines, Department of Commerce. Tin imports have annually exceeded $60,000,000 in value, but domestic mine production was worth less than $11,000 for the last year of record. Moreover, the net imports of tin exceed, in value, those of any other mineral product, and the metal is among the ten leading commodities imported. The principal tin-consuming industries are food-packing, automobile manufacture, and building.

A few years ago, when the price of tin was approximately double what it averages now, the opinion was widely expressed that the reserves of tin, marketable at the prices then current, were very limited. This resulted in intensive research for substitutes. The field for making important substitutions seemed very promising because at that time tin was the highest-priced metal in the common base-metal group. Since the fall in the price of tin the search for substitutes has diminished, but domestic consumers depend on substitutes as one of their most effective means for maintaining reasonable tin prices.

Much study has been given the problem of finding a substitute for tin-plate in the canning industry, but to date no tin-free container has been developed that can offer serious competition to the tin can. Glass containers have been used successfully where the advantage of display of contents has outweighed the higher initial cost and difficulties of transportation. Aluminium is being used as a substitute for tin in the manufacture of foils and collapsible tubes. Because of its low specific gravity a given weight of aluminium will make much more foil of a given thickness than an equal weight of tin; but this advantage is offset in some tin foils by rolling from bars containing a lead core. Tin foil is also meeting severe competition as a food and cigar wrapper in "Cellophane," a transparent cellulose product, and in various waxed papers.

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part XII.—Rolling Operations.

The preliminary rolling operations on aluminium slabs prior to finishing to gauge in the production of sheet and coil are described.

THE preliminary rolling operations on aluminium slaps in reducing the thickness, previous to the finishing passes, may be referred to broadly as roughing. As has been mentioned in previous articles of this series, all rolling operations on aluminium and its light alloys, starting with the hot-mill slab, are ordinarily carried out at room temperature. The only exception to this is found in the practice where slabs are sent directly from the hot mill to a continuous mill and roughed to nominal gauge at about 250° C.

In different works, such terms as slabbing, roughing, re-roughing, and running-down are used to describe various steps in the preliminary rolling. Thus, in American practice the first roughing on sheet slabs, as carried out on two-high non-reversing mills, is known generally by the term slabbing, and the subsequent rolling operations, previous to finish rolling, are called roughing. Also, the preliminary break-down operations on coil slabs, as carried out on two-high reversing or non-reversing mills, are referred to as roughing in some plants and as running-down in others. In one mill the term running-down is applied only to the third roughing on coil—*i.e.*, the roughing operation just previous to the finish rolling. In some plants, the first roughing or slabbing (*supra*) on sheet slabs is called roughing, and the second roughing is referred to as re-roughing. The run-down of sheet or coil slabs on a continuous mill is called slabbing in one works. Finally, the term slabbing is used in another plant to apply to any preliminary cold rolling up to an annealing, previous to finish rolling, and the term roughing is applied to preliminary rolling after an annealing.

Regardless of the terminology employed, the primary purpose of roughing is to reduce the thickness of the hot-mill slab as rapidly as feasible, and prepare the stock for the final passes, whereby the desired gauge (and surface finish) is attained. Perhaps, in passing, it is well to say that roughing assumes equal importance with finish rolling in the processing of aluminium-sheet products since stock which has not been properly roughed cannot be properly finished.

STOCK AND SLAB SHEARING.

The term stock-shearing may be applied to the squaring of ends and trimming of sides of hot-mill slabs before cold rolling. When slabs are cut to length—*i.e.*, a slab is sheared into two or more pieces of specific length as called for by the planning, the operation may be referred to as slab shearing. This may be done before or after slabbing—usually before roughing. Also, when a coil slab is cut in two longitudinally before the first roughing, the operation is referred to as slab shearing. Stock and slab shearing are done largely on heavy-duty power shears of the guillotine type. There is, however, ample scope for the use of automatic flying and squaring shears in the aluminium rolling mill. Edge stock-shearing losses in the case of coil stock may be substantially reduced by side trimming with a heavy duty slitter after the first roughing.

Stock shearing, so-called, is applied for the most part to coil slabs before cold rolling. In some plants where slabs for coil production are given the first roughing on two-high reversing or non-reversing mills, the slabs are sent to the stock shears from the hot mill. The shearing consists in squaring the ends (pieces, say, 3 in. to 5 in. being cut off each end), and cutting strips $\frac{1}{2}$in. to 1 in. wide off each side. Slabs are squared on the ends, so that they can be easily started straight into the roll opening on the first roughing. If slabs are not squared, they may not roll straight, and hence may cause damage to the mill. In some plants it is practice to shear off a longer piece from the end of the slab corresponding to the top of the ingot (in the case of ingots poured in vertical, tilting-book moulds) than from the other end. This is for the purpose of removing drossy or spongy metal resulting from the final freezing in the head. Coil slabs are trimmed on the sides to provide straight edges, remove any slightly ragged metal, and prevent further cracking in on roughing. The above discussion applies more particularly to 99 + % aluminium and the softer alloys.

Fig. 1 shows a large power shear used for side-stock shearing. The nominal cutting length of stock shears may be up to 156 in. or longer, as required. Shears of the same type as shown in Fig. 1, but with cutting length of up to about 60 in., may be used for slab shearing.

As an alternative to the shearing operations above described, coil slabs may be squared on one or both ends

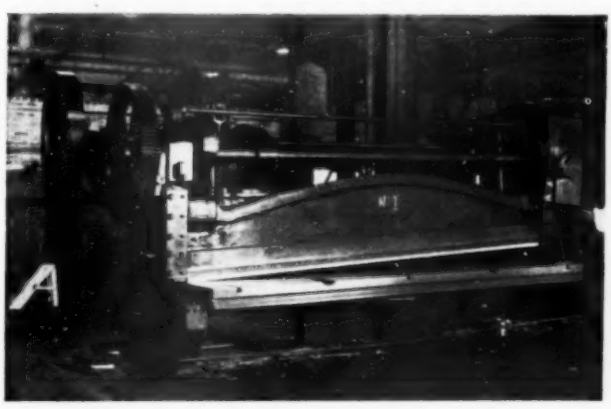


Fig. 1.—Large Power Shear used for Stock Shearing.

and then roughed to nominal thickness—say, 0·1 in. The edges are trimmed as the roughed slab comes off the mill on the last pass. For this purpose a combination heavy-duty slitter, scrap-cutter, and coiler is "ganged-up" with the mill. This machine slits a strip off each edge, thereby removing the ragged edges and producing stock of the required width, cuts up the edge strips into short pieces, and delivers the material in the form of coils.

When slabs are run down to nominal gauge on a continuous mill, being passed directly from the hot mill, the edges may be trimmed as the roughed slab emerges from the last stand. The stock is passed through a combination slitter, scrap cutter, and coiler as mentioned just above. Trimming the edges of coil slabs after the first roughing yields less scrap than side-shearing on a power stock shear before roughing and produces coils with straight edges—this latter being advantageous for the subsequent roughing and finishing. Fig. 2 shows a combination slitter and coiler, such as is "ganged-up" with a continuous mill.

Passing now to the shearing of hot-mill slabs for flat-sheet production, in some plants the material is not sheared until after the slabbing operation unless badly cracked. Thus, the hot-mill slabs are sent to a two-high slabbing mill, cold-slabbed to the required thickness, and then the

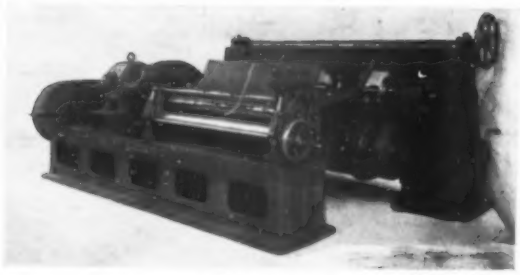


Fig. 2.—Combination Slitter and Coiler (The Torrington Mfg. Co.).

stock is cut to length. Slabs for narrow sheet may be cut in two before cold slabbing, so that they can be handled more easily, the two separate pieces being subsequently cut to lengths before roughing. The matter of "slab cuts" has been discussed in the previous article of this series dealing with planning methods. In cases where stock is not annealed in the slab before slabbing or is roughed without intermediate annealing, it may be found advisable to trim the edges and square the ends before starting the slabbing operation.

After roughing sheet stock, the ends may be squared to prevent splitting in on finish rolling. However, this operation may be omitted if the roughed sheets are fairly square as to ends and not cracked in. Packs may require trimming on both ends and sides after roughing; sheets roughed in pack tend to crack in as the pack is built up on roughing. In most mills, any large ends resulting at the slab shear are classified as to size and thickness, and laid aside as slab stock to be used for small orders or to make up shortages.

Stock and slab shears are operated by a shearman and one or two helpers, depending on the size of the slabs handled. After shearing, the material is sent to the proper mill for cold rolling.

In the case of duralumin, hot-mill slabs for either flat-sheet or coil production may be trimmed after hot rolling to remove cracked edges, and again after the second roughing for the same purpose, and to obtain the desired size. Shearing losses with the harder alloys are considerably higher than with the commercially pure metal.

SLABBING FOR FLAT-SHEET PRODUCTION.

The preliminary roughing of hot-mill slabs for flat-sheet production may be done on divers types of rolling mills, including two-high non-reversing, two-high reversing, three-high, four-high, and two-high continuous mills. Practice is necessarily very variable in different plants depending on the available equipment.

In some works, aluminium is slabbed on ordinary two-high non-reversing sheet mills of the same type used for the finish rolling of flat sheets. The slabs are passed into the mill by the roller (and helper, in the case of large slabs), and returned over the upper roll by one or two catchers.

Fig. 3.—Two-high Slabbing and Roughing Mills.

Mills having rolls measuring, say, 24 in. to 28 in. in diameter and 60 in. to 84 in. (and up to 120 in.) long are used in American practice for cold slabbing. In the case of mills with chilled cast-iron rolls, the rolls are run with a coating. The thickness to which the slabs are reduced on slabbing depends on various factors, including the original thickness and the finished gauge and temper. In some plants, the cold-slabbing operation consists in reducing all slabs 50% in thickness before roughing, whereas in others the metal is reduced to nominal gauge—say, No. 8 to No. 12 Brown and Sharpe gauge. Where metal must be annealed at some thickness reached during cold slabbing, in order to produce an intermediate temper, such as 2 S 8, then the reduction may be carried to the annealing point on the slabbing mill, and the metal is further reduced on a roughing mill after annealing.

Aluminium is broken down with fairly heavy reductions on cold slabbing. Thus, slabs $\frac{1}{4}$ in. thick are rolled to $\frac{1}{8}$ in. with about six passes and two or three sets of the rolls. For wide flat sheet, the slabs should be rolled so as to leave a fairly heavy centre; this will tend to prevent pinching on roughing or finishing. The spring in wide rolls (ground flat) on heavy reductions will normally tend to leave a heavy centre in the slabbed product. In slabbing, the rolls should be swabbed occasionally with kerosene to prevent the metal from sticking to the roll surfaces. The application should be made sparingly.

TABLE I.

Thicknesses to which Hot-mill Slabs are Cold Slabbed for Various Gauges and Sizes of Aluminium Sheet.

Finished Gauge to be, B. and S.	Finished Width to be, In.	Finished Length to be, In.	Cold Slabbed to Thickness, In.	Remarks.
1 to 11	*	*	Not slabbed	Finished from the hot-mill slab.
12 to 13	*	*	0·15 or 0·125	Roughed
14	*	50 to 124	0·15 to 0·125	Roughed
14	*	124 to 160	0·15	Roughed
16	*	110 to 124	0·125	Roughed
16	*	124 to 164	0·125	Roughed
17 to 25	36 and over	*	0·125	Roughed
17 to 25	Up to 36	*	0·10	Roughed
26 to 40	*	*	0·10	Roughed

* Indicates practically any length or width.

At one plant, hot-mill slabs are cold slabbed to the thicknesses shown in Table I., which gives the variation of slab thickness with finished gauge and size. As indicated, sheets to finish heavier than 12-gauge are not slabbed; for such material, ingots are hot rolled to thicknesses as follows:—

Finished Gauge, B. and S.	Hot Rolled to In.	Finished Gauge, B. and S.	Hot Rolled to In.
1 to 4	0·50	8 to 9	0·25
5 to 7	0·30	10 to 11	0·20

Heavy-gauge material is given suitable roughing and then finish rolled, the slabbing operation being omitted. In the same plant, it is practice to hot-roll slabs, for sheet to finish lighter than 11-gauge, to twice the thickness of the slabbed slab. That is to say, the hot-mill slab is made of such thickness that it can be reduced 50% on slabbing, and still have sufficient thickness for roughing and finishing. Slabs for extra large sheets may be slabbed heavier than shown in the table. Thus, material to finish 14- or 16-gauge and 130 in. to 164 in. long, may be slabbed to 0·20 in. Rate of production in slabbing on two-high non-reversing mills is variable, but an indicated average for run-of-mill production is about 2,000 lb. per hour.

Fig. 3 shows a view of a pair of two-high non-reversing flat-sheet mills as used for slabbing and roughing. The photograph was taken from the roller's side. Piles of stock will be noticed on the feed tables.

Slabs for narrow, bright flat sheet may be run down in the same manner as coil stock (*cf.* Roughing Coil Slabs,

(*Continued at foot of next page.*)

Testing of Materials for Service in High-temperature Steam Plant.

WHEN materials of construction are submitted to service conditions at normal temperatures the problems associated with the design of mechanism are not difficult, because, in the majority of instances, tests have been devised which give very full information respecting the ability of a material to withstand stresses, and dimensions of parts can be calculated according to the materials used and the stresses to which they are to be subjected. But when the materials are required for high temperatures under such conditions that steel and most other alloys act very much as lead does at room temperature, the problems involved in designing are more complex. The engineer naturally desires precise information on the properties of materials to be subjected to high temperatures in order that he may know at just how high a temperature the material will give efficient service. While this situation has long existed, it is only during comparatively recent years that new materials and new data demanded by the engineer have been forthcoming in any great measure. The development of the heat-resisting steels is one valuable contribution to improved materials required, but while chromium and nickel are the vital elements in such a large proportion of the alloys used for this purpose, the tendency is toward embrittlement of the otherwise useful 18–8 alloy, as well as the straight iron-chromium alloys, and considerable research with a view to the elimination of this fault leads to the belief that some modification is likely to be met in such alloys.

The remarkable complexity of the properties of metals, when the temperature to which they are subjected rises, it is necessary to evaluate limiting stresses in order that suitable metals or alloys can be used with security and economy. Until recent years, as long as the condition of a metal and its physical properties were for practical purposes permanent, the usual mechanical tests were sufficient. Evidence is rapidly accumulating, however, that the idea of comparative permanence in properties and dimensions to which long experience in the use of metals at atmospheric and moderate temperatures has accustomed engineers is untenable when elevated temperatures are concerned. The subject is a very large one, and present knowledge of parts is insufficient to permit of careful consideration in a single paper. Thus, in a paper before the Institution of Mechanical Engineers, recently, Messrs. R. W. Bailey and A. M. Roberts confined their attention to the conditions occurring in a specific branch of engineering industry, more particularly to the requirements of steam-power plant operating at high temperatures.

The attention of the Institution of Mechanical Engineers was first focussed upon what has become known as the phenomenon of creep of metals by the work of Lea,* who made long-duration tests upon steels at temperatures of immediate importance in connection with steam-power plant. Subsequent research and experience have shown that for safety appreciably lower stresses must be employed than Lea's early work indicated, and, generally, progress in knowledge has confirmed the inadequacy of the usual tests to determine the suitability of metals for high-temperature service. As a consequence, there is a growing recognition by engineers interested in the use of metals at elevated temperatures, of the need for additional or new tests designed and defined to satisfy the requirements of high-temperature service. This need remains unsatisfied, and much further work requires to be done before it can be provided for completely. The authors express the opinion, however, that on account of the increasing employment of metals at elevated temperatures and the apparent differences frequently found in the results of tests by different investigators, the time has arrived when the several aspects of the problem may be usefully considered, and that, if it is found practicable, preliminary steps may be taken to define tests and indicate conditions of testing for general use.

The authors review the subject in relation to steam plant very fully, and although the scope is limited, some of the matter is of a more general character and application. As a result of this limitation, interest for practical purposes is centred upon steels and operating or testing temperatures below 600° C. Any treatment of the subject within this scope is handicapped by several limitations, not the least of which is the long times occupied in obtaining data, and its consequent limited extent unless many investigators are engaged. The authors, however, have presented by way of example sufficient information to convey what they regard as important features in testing metals for prolonged use at elevated temperatures, where it is desired to obtain beforehand a reliable indication of the behaviour to be expected. Structural changes of certain carbon steels as affected by prolonged thermal action have been found to conform with a general law which may be utilised for creating in material to be tested the changes that may be expected to result from long service. By this means a nearer approach may be made to the actual condition of the material as it will be found in service, than by testing in the "as received" condition. The authors believe that the case of alloy steels in various conditions will conform to similar laws. There is an important field for further research in investigating the behaviour of such steels.

* Lea, F. C., "Effect of Low and High Temperatures on Materials," Proc. I. Mech. E., 1924, vol ii., page 1,053.

Aluminium Sheet Production,

Continued from previous page.

below) to within a few gauge numbers of the finished gauge. The coils are then cut into lengths, flattened, and the material rolled to gauge on flat-sheet mills.

Slabs for flat sheet to finish up to, say, 40 in. wide, may be roughed from about $\frac{3}{8}$ in. thick to $\frac{1}{8}$ in. on a two-high continuous mill. The slabs may be broken down directly from the hot mill, or rolled cold. At one plant, the reductions per stand in a seven-stand continuous mill (not using the second pair of rolls), in rolling sheet slabs from $\frac{3}{8}$ in. to $\frac{1}{8}$ in. thick, are as shown in Table II. If slabs are broken hot—*i.e.*, at about 250° C.—on a continuous mill, a mixture of so-called soluble oil and water, such as is used in the hot break-down operation on ingots, may be employed as the lubricant. If rolled cold, a mixture of metal oil and kerosene, such as is used in general rolling operations on aluminium coil stock, may be employed as the lubricant.

TABLE II.

Reductions per Pass: Flat-sheet Slabs Rolled on a Continuous Mill.

Stand No.	Slab Thickness, In.		Reduction in Thickness.	
	Entering Rolls.	Leaving Rolls.	In.	%
1	0·375	0·300	0·075	20
3	0·300	0·230	0·070	23
4	0·230	0·185	0·045	20
5	0·185	0·155	0·030	16
6	0·155	0·135	0·020	13
7	0·135	0·125	0·010	7

In roughing hard alloys, such as duralumin, the hot-mill slabs, rolled to, say, $\frac{3}{8}$ in. thick or a little less, are annealed, and then given a first roughing to about 0·18 in. thick. After another annealing, heavy-gauge material is finished directly from the roughed stock; light-gauge sheet, or coil, is given a second roughing to about 0·08 in. thick, again annealed, and sent to the finishing mills. The stock is side trimmed after the second roughing.

In some plants, hot-mill slabs are given the heavy roughing (slabbing) on two-high reversing mills, and in other works on three-high mills. A four-high mill, of the type recently adopted in steel practice for rolling wide strip, has been installed in an American plant for the heavy roughing operation on duralumin slabs.

(*To be continued.*)

Institute of Metals

Twenty-fourth Annual General Meeting

THE Council of the Institute of Metals are a resourceful body, and the members of the Institute have not been slow to appreciate the initiative displayed during recent years in maintaining the organisation in a live condition. The report of the Council for the year ending December 31, 1931, presented at the annual meeting held in London, March 9 and 10, indicates its progressive character. The fact that the Institute has passed through twelve months of great economic stress without being compelled to curtail its activities or to diminish in any way its services to its members, to science, or to industry, is a tribute to the able manner in which the business of the Institute is conducted. It is noteworthy that a further increase in membership is recorded, and the recent annual meeting gave evidence that interest is well maintained.

Sir Henry Fowler, in his presidential address, referred to what has become a custom—for the presidency of the Institute to be held successively by a producer, or manufacturer of non-ferrous metals; by a member engaged in academic pursuits and investigation; and by one who is a user of the metals with which the Institute is concerned. Sir Henry has been concerned with many phases of engineering work, and is representative of users, as exemplified in the manufacture and use of steam engines generally. He commented on the facilities which now exist for the teaching of metallurgy and for research in the subject. No engineer, he said, can be properly equipped for his work unless he has some knowledge of metallurgy. Discoveries of the metallurgist greatly facilitate the work of the engineer and in some cases revolutionise it. He stressed the need for improvements to be given a practical test as early as possible, because of the time involved in assessing their practical value.

At the technical sessions, which followed the business meeting, fourteen papers were presented for discussion, and the meeting concluded with a general discussion on the testing of castings, which was introduced by Dr. W. Rosenhain. It is only possible to briefly summarise the papers, all of which were well received.

RELATIVE CORRODIBILITIES OF FERROUS AND NON-FERROUS METALS AND ALLOYS.

The third and final report on the relative corrodibilities of ferrous and non-ferrous metals and alloys was presented by Dr. J. Newton Friend. In this research nearly one hundred bars of ferrous and non-ferrous metals were exposed to sea action in Southampton Docks for three years. The bars were supported in frames and fixed under a jetty at approximately half-tide level. The metals examined included lead, zinc, tin, aluminium, copper, nickel, and various alloys containing iron, chromium, nickel, copper, and zinc.

Owing to the thick accumulation of mud and shelly faunæ, it was not possible to gauge the extent of corrosion excepting by dismantling the specimens. This was unfortunate, as it was found that corrosion had not proceeded as far as had been expected, and the results are not as conclusive as the author had wished. The oil from ships assisted in the formation of a more or less protective layer of mud round the bars, which had not been scoured off by the slowly moving waters. The present results, therefore, are not exactly comparable with those previously obtained from specimens exposed to sea action at Weston-super-Mare.[1]

The effect of grain size on the corrodibility of brass has been studied. Specimens of identical chemical composition, but differing in grain size, gave results which appear to indicate that small grain is preferable to coarse. Nickel-copper alloys, particularly the 70–28 alloy (Monel metal), offered great resistance to corrosion. High-grade zinc and tin were slightly more attacked than the less pure metals. The effect of arsenic in slightly retarding the corrosion of copper exposed to alternate wet and dry sea-action is supported.

Tension, riveting, and cold working did not appreciably affect the corrosion of nickel-chromium alloy steels, but in every case cracks appeared at welds. Shell faunæ did not appear to affect the corrosion of the metals appreciably while living, but dead faunæ stimulated localised corrosion in alloy steels, nickel, and nickel alloys not rich in copper. The alloy steels resisted corrosion well, but previous results showing that alloys steels are subject to localised corrosion are confirmed.

THE PROPERTIES OF COPPER IN RELATION TO LOW STRESSES.

Part I.—Tensile and Compression Tests under Short-time Loading.

In some previous work carried out by the British Non-ferrous Metals Research Association on the subject of locomotive firebox stays and plates,[2] the marked effect of work-hardening followed by low temperature heat treatment on the elastic properties has been demonstrated. The results of this research also indicated the beneficial influence of the addition of quite small amounts of silver and other constituents in raising the temperature limit at which loss of elasticity and softening occur. The recognition of the potential wider application of copper with such improved properties has led to further work by Messrs. O. F. Hudson and J. McKeown, the results of which were presented at this meeting. The work deals with the effect on the tensile properties, especially the elastic limit, and on the resistance to tensile and compressive stresses at moderately elevated temperatures, always in relation to the influence of pre-treatment by cold-working and low-temperature heat-treatment, together with the influence of the composition of the copper.

Five types of copper have been studied—namely, H.-C. copper; arsenical copper with and without the addition of silver (0·05–0·1%); copper containing about 0·1% silver, without arsenic; and copper containing about 1% tin and about 0·02% silicon. Rods of these materials with known amounts of cold work have been subjected to heat-treatment for various times at different temperatures, and tensile and compressive tests have been made. Tensile tests were carried out at room temperatures and at 300° C., and compression tests were made at 300° C. and also at 350° C.

The tensile tests have shown that all the materials tested possess a certain limit of proportionality, due to the applied cold work, and that this limit of proportionality can be considerably raised by suitable heat-treatment. The amount of permanent deformation due to stresses not greatly exceeding the limit of proportionality have been measured in tension at ordinary temperatures, and in compression at 300° C. and 350° C. The results have shown the superior resistance to deformation brought about by cold work and suitable heat-treatment, and have also demonstrated the greater resistance to deformation conferred on copper, particularly at elevated temperatures, by the presence of a very small percentage of silver and also by the presence of tin and silicon.

1 *J. Inst. Metals*, 1928, 39, 111.

2 *J. Inst. Metals*, 1929, 42, pp. 221-319.

The marked superiority of the properties which have been shown to be readily achieved by pre-treatment should warrant the attention of engineers and other users of copper, where resistance to deformation under low stresses is of importance, as it is in so many applications. The choice of the alloy will no doubt largely depend on economic and manufacturing questions, but the use of the low-silver alloys may in many cases be preferred, despite the high cost of silver, in view of the persistence with which the silver content is retained throughout even large-scale melting operations.

Part II.—Creep Tests at 300°C. and 350°C. of Arsenical Copper and Silver-arsenical Copper.

An investigation on samples of two alloys of the type referred to in Part I.—namely, arsenical copper and silver-arsenical copper, soft and also cold-worked,—followed by moderate-temperature heat-treatment, with the object of determining their relative resistance to creep at 300° C. and 350° C. under prolonged loading conditions, has been carried out at the National Physical Laboratory. The results of this work by Messrs. H. J. Tapsell and A. E. Johnson show that the initial strains on loading deform the soft alloys initially to a greater extent than the pre-heated alloys. The presence of silver in some of the samples does not appear to have a marked effect on the initial deformation under tensile load (2–5 tons per sq. in.), except that a reduction in initial deformation at 300° C. seems to be brought about by its presence in the pre-treated alloy. The investigation shows that improvement in resistance to creep at 300° C. and 350° C. is effected by the special pre-treatment of the alloys, and that the alloys containing 0·072% silver are superior to the silver-free alloys.

THE INTERACTION OF ALUMINIUM AND WATER VAPOUR.

The view has been expressed recently that aluminium and its alloys are rapidly attacked by superheated steam at 300°–350° C. The matter being of interest, both practically and theoretically, Messrs. R. Seligman and P. Williams have re-examined it and presented the result of their investigations in the form of a note. Two experiments were made on samples, one at atmospheric pressure and the other at a pressure of about 6·7 atmospheres. The authors were not concerned with quick movement of their steam, which would only facilitate chemical attack by the mechanical removal of protective films, but they made sure that no water touched their test-pieces. In one case the amount of air present was also reduced to far below that required to form the protective film. The results of the experiments indicate that no such attack takes place under the conditions existing in these investigations.

THE ELASTIC BEHAVIOUR OF VARIOUS LIGHT ALLOYS.

The light metals—aluminium and magnesium,—or alloys containing them in appreciable quantities, are now used for a wide range of purposes, in which they are subjected to extreme climatic conditions, and it is necessary, for economical construction and safety in use, to study carefully the behaviour of these materials under the influence of conditions to which they may be subjected. In particular, the strength of these materials is appreciably affected by elevated and abnormally low temperatures, and the influence of these on the elastic properties is determined by experiments which have been carried out by Dr. Franz Bollenrath and are described in this paper. Complete details are given on the experimental determination of the modulus of elasticity and elastic limit of various wrought aluminium and magnesium alloys at temperatures between − 190° C. and + 180° C. The latter temperature was selected because the resistance of aluminium alloys which have been improved by natural or artificial ageing is, in many cases, impaired by subjection to temperatures of this order, and because tests made of this or rather lower temperatures serve to show how the improvement which has been effected by the ageing process may be lost again in regard to the elastic behaviour.

The testing apparatus is described, as also are the alloys tested, and the results obtained from the experiments are discussed. It is found that the elastic properties increase with decreasing temperature, except in the case of two alloys with a high silicon content.

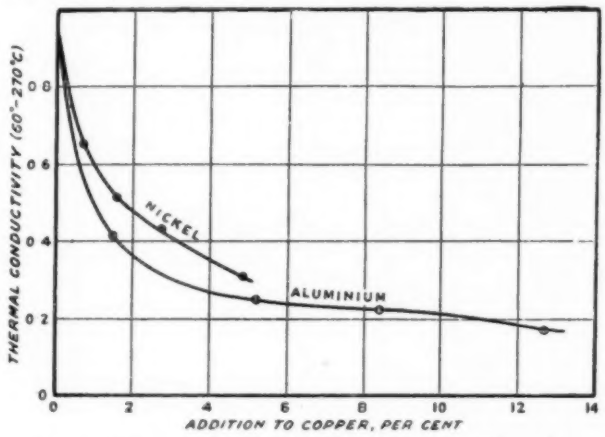


Fig. 1.—Effects of Nickel and Aluminium on the Thermal Conductivity of Copper.

THE THERMAL CONDUCTIVITY OF SOME NON-FERROUS ALLOYS.

This paper describes the results of thermal conductivity tests by Professor D. Hanson and C. E. Rodgers on a series of aluminium-copper alloys, and also the effects of some elements on the thermal conductivity of copper. Tests on specimens of copper-aluminium alloys in the "as cast" state and after annealing at 500° C. for 24 hours and cooling in the furnace, reveal the fact that bars in the "as cast" state have a much lower conductivity than annealed bars. The authors state that this is probably due to the retention of a greater amount of copper in solution in the chill castings, while on annealing much copper is no doubt precipitated during cooling in the furnace. The

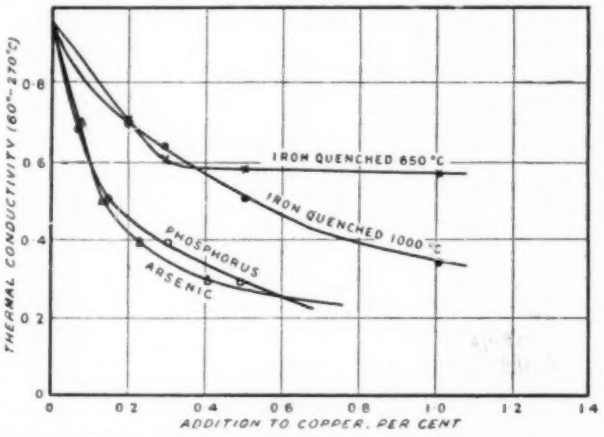


Fig. 2.—Effects of Iron, Phosphorus, and Arsenic on the Thermal Conductivity of Copper.

tests on these alloys clearly indicate that thermal conductivity is greatly affected by the heat-treatment to which they are subjected, and the authors suggest that further work is required on this subject.

The results of tests to determine the influence of aluminium and nickel on the thermal conductivity of copper are shown in Fig. 1. The specimens were tested in the annealed state, at 500° C. in the case of the aluminium

alloys, and the nickel alloys at 900° C. The influence of iron, phosphorus, and arsenic on the thermal conductivity of copper is shown in Fig. 2. The effect of iron is influenced by heat-treatment, a greater amount being held in solution at the higher temperature to which some of the specimens were subjected.

INTERCRYSTALLINE CORROSION OF DURALUMIN.

Under certain conditions of use, duralumin has sometimes been found to develop a form of corrosion which penetrates below the surface of the material and is not necessarily accompanied by visible corrosion product on the surface. In the early stages the general effect of this form of attack, which is intercrystalline in character, is a marked reduction in the ductility of the material and a somewhat smaller decrease in maximum strength. Many investigators have studied duralumin with the object of determining the cause of this deterioration. In this paper Messrs. A. J. Sidery, K. G. Lewis, and H. Sutton describe experiments they have made to determine the effect of overstrain, and also of certain modifications of heat-treatment on the tendency of duralumin towards intercrystalline corrosion. For the purpose of evolving a reliable test which would permit the relative susceptibility of the various samples of duralumin to this form of corrosion to be estimated in a reasonable space of time, several reagents were investigated. It was found that partial immersion in an N-1 solution of sodium chloride, to which 1% (by weight) of hydrogen chloride had been added, was capable of producing intercrystalline corrosion consistently in samples of duralumin, where a propensity towards this type of corrosion existed.

The effect of overstrain was examined by subjecting to this test a number of specimens of heat-treated duralumin sheet to which tensile stress had been applied to produce various degrees of permanent elongation and a number of longitudinal strips cut from samples of heat-treated duralumin tube which had been compressed to arbitrarily selected stresses above the elastic limit in compression. The results of the experiments indicated that overstrain in tension increased slightly the tendency towards intercrystalline penetration, but no relation was observed between this tendency and the degree of elongation. There appeared, however, to be a critical range of stress in compression—viz., 14·0–16·9 tons/sq. in.—for the material employed in the experiments. Samples which had been compressed in this range of stress showed the greatest susceptibility.

Corrosion tests were made on samples of the sheet and tube which had been heated at various temperatures in the range 470°-520° C., quenched in cold or in boiling water, and aged at room temperature with a view to ascertain the influence of such modification of heat-treatment and of quenching medium on the susceptibility of the material to intercrystalline attack.

The results of these tests indicated that the higher the quenching temperature, the smaller was the tendency of the material to develop intercrystalline corrosion. In the material quenched from the higher temperatures employed, there was, however, an increased tendency towards the pitting form of superficial corrosion. In samples quenched in boiling water, the tendency towards intercrystalline corrosion was much greater than in those quenched in cold water.

MAGNESIUM ALLOY PROTECTION.

A process for the protection of magnesium-rich alloys, particularly those used in aircraft construction, against corrosion by the atmosphere and chloride solutions, especially sea-water spray has been developed by Messrs. G. D. Bengough and L. Whitby. Specimens of a number of alloys were given chemical immersion treatment to produce a protective coating, and these were suspended vertically in a field and sprayed three times daily with sea-water. Of many solutions used for producing coatings on the specimens, the best results were obtained with a tungstate-chromic-nitric acid bath and a selenite bath, particularly for the A Z M alloy. Since the selenite bath was the simpler, the investigation was concentrated on it, using A Z M, A M S O 3, and V 1 alloys, which apparently are the most useful alloys. Two solutions were selected for use—viz. :—

1. 8% solution of selenious acid in water + 0·1 — 0·5% sodium chloride.
2. 10% solution of selenious acid in water + 0·1 — 0·5% sodium chloride.

Each was used at atmospheric temperature, and the samples were immersed for periods of 5 to 10 mins. Most of the work was done with the second bath, which is only slowly exhausted. For instance, forty specimens were treated successively in 500 c.c. of 5% selenious acid. After eight weeks' testing with the salt spray, no difference could be detected between the first and last specimen. Although the best films were produced by dipping the specimens in the bath, this procedure was found to be not absolutely necessary. Protective films were obtained by merely rubbing specimens with cotton wool saturated with the second solution. This process offers an easy method of repairing the film if it should be locally damaged, and would be a great advantage in industrial use.

It was found that the film has the property of self-heating to a limited extent, especially when immersed in stagnant sea-water. The production of the film, which is only a few thousandths of a millimetre thick, does not cause any appreciable dimensional change in the alloys treated, and it forms a satisfactory base for certain types of paint, but a comprehensive investigation is at present in progress on the effect of both pigment and medium on selenium-coated metal.

THE AGE-HARDENING OF SOME ALUMINIUM ALLOYS OF HIGH PURITY.

The anomalous behaviour of alloys of high-purity aluminium with copper which age-harden at room temperature, in contrast to similar alloys made from commercial aluminium, has been investigated by Dr. Marie L. V. Gayler and C. D. Preston, in an endeavour to determine the reason for this phenomenon. The investigation into the age-hardening of a series of alloys containing 4% copper made with high-purity aluminium, to which iron, silicon and magnesium have been added either independently or together, has confirmed the results of previous investigators. It has been shown that the addition of 0·35% iron inhibits the age-hardening at room temperature of the binary copper-aluminium alloys: this effect is partly removed by the addition of 0·25% silicon, and is entirely removed by the addition of 0·5% magnesium. X-ray and microscopic examination have failed to give an explanation of the phenomena observed during age-hardening at room temperature.

The conclusions are drawn that (1) age-hardening of a duralumin at room temperature and at 200° C. is due to some process, as yet undefined, which takes place prior to actual precipitation of $CuAl_2$ or Mg_2Si from the aluminium lattice; (2) in conjunction with existing equilibrium data, it is suggested that Mg_2Si as well as $CuAl_2$ plays an important part in the process of age-hardening.

SOME BRONZE SPECIMENS FROM UR.

The microstructure and results of chemical analysis of some bronze object found by Mr. C. L. Woolley, during his excavations of the Royal Graves at Ur, are presented in a paper by Dr. C. F. Elam. Previous reports on similar objects have dealt chiefly with the chemical composition of ores, with a view to tracing the copper supply from which the metals were manufactured. This is particularly interesting because of the presence of nickel in so many of the objects. In this paper, however, the general appearance and microstructure of some of these objects are

examined. The approximate composition has been determined, and qualitative tests have been made of the corrosion products. It is stated that some of the objects have been cast, while others showed signs of subsequent working and annealing.

THE "FOGGING" OF NICKEL.

The brilliant lustre and high degree of whiteness that characterise the surface of polished nickel constitute an important factor in the wide application of this metal as a protective and decorative coating. An offset to this, however, is the readiness with which the metal assumes, under many conditions of exposure, a dull creamy film, whereby the initially high reflectivity is rapidly obscured; this phenomenon may conveniently be described as "fogging."

A study of this characteristic has been made, and is presented in a paper by Dr. W. H. J. Vernon, the object of which is to give a connected statement of the subject and to record the results of certain experiments which have been conducted recently.

The "fogging" of nickel consists in the formation of a creamy-white film on the polished surface of the metal. In the early stages the film contains nickel sulphate with associated sulphuric acid; it can then be removed readily by wiping with a cloth; subsequently its removal is effected with greater difficulty, and finally it cannot be dislodged without abrasion of metal. In this condition the film consists of basic nickel sulphate. Copper, when alloyed with nickel, is neutral in respect to its influence on fogging, the tendency to fogging of copper-nickel alloys being proportional to the nickel content. Chromium, on the other hand, has a marked inhibitory effect. Thin films of grease effectively prevent fogging; lanoline is superior to vaseline for this purpose when the thinnest films are concerned.

For the initial condensation to take place, the relative humidity of the atmosphere must exceed a certain critical value in the neighbourhood of 70%; at lower relative humidities the metal remains bright indefinitely. Fogging is due partly to the presence of suspended sulphates in the air, and partly (probably mainly) to the presence of small amounts of sulphur dioxide, which are catalytically oxidised at the metal surface when the critical humidity is exceeded. The fogging process is affected by light, film formation being approximately halved when light is completely excluded. Prolonged exposure of polished nickel to stagnant air at ordinary temperatures induces a large measure of immunity to fogging on subsequent free exposure. This effect, which cannot be reproduced by short periods of exposure at higher temperatures, is probably due to the poisoning of the nickel surface by traces of an anticatalyst. A similar effect has been induced artificially by traces of hydrogen sulphide.

BEHAVIOUR OF SINGLE CRYSTALS OF BISMUTH SUBJECTED TO ALTERNATING TORSIONAL STRESSES.

For some years past there has been in progress at the National Physical Laboratory a research into the characteristics of the deformation of large single crystals of metals under various types of static and repeated stresses. The chief aim of the research is to determine the nature and causes of the failure of metals by fatigue action, and in all the experiments attention is directed primarily to the phenomena directly connected with fatigue failure. On the other hand, in several experiments recently performed a number of phenomena have been observed, which, whilst having little or no bearing on the actual problem of fatigue failure, appear to be of considerable interest from a purely metallurgical point of view. Thus, in the case of zinc and antimony information was obtained as to the mode of formation of twin bands, whilst in the case of silver the entire absence of mechanical twinning on the surface of a single crystal fractured under alternating torsional stresses has been recorded. Again, in the tests on bismuth, described in a paper presented by Dr. H. J. Gough and H. L. Cox, the primary object of the experiments was to determine the slip plane and direction; but whilst, owing to the complete absence of slip, this object was not achieved, the profuse twinning caused by the alternating torsional stresses enabled the factors governing the formation of twin bands to be investigated in some considerable detail.

In the early stages of the tests on two single crystals of bismuth numerous bands were produced parallel to the twinning planes, and finally cleavage cracking occurred. The bands parallel to the twinning planes could not be definitely identified as twin bands by metallographic examination; but evidence as to this identity was finally found in the cracks observed on the surface of one of the specimens. Some signs of recrystallization were observed, the effect tending to extend along the sites of twin bands.

The production of twin bands appeared to depend on the shear stresses on the twinning plane, and consideration is given to the theoretical reasons for this dependence. It is shown that on the basis of minimum energy there is no reason to associate any type of movement with stresses tending to cause this movement by the shortest geometrical path, and that the process of twinning may be due to stresses which at first sight appear to be incapable of affecting the process.

THE SOLUBILITY OF ALUMINIUM IN MAGNESIUM IN THE SOLID STATE AT DIFFERENT TEMPERATURES.

The solubility of aluminium in solid magnesium is of interest in connection with the structure of alloys of the elektron type, in which magnesium is the principal constituent, and the age-hardening properties are the result of changes of the solubility of the other element with temperature. Previous investigations had shown differences between results and the present research by Professor P. Saldau and Mr. Zamotorin was undertaken with the object of throwing further light upon the problem. As a result of this research the solubility of aluminium in magnesium of 99·68% purity has been determined at temperatures up to 420° C. The solubility limit at room temperature is 6·08% aluminium by weight, and this is maintained unchanged until 300° C., after which a rapid increase occurs, the solubility line passing through 10·9% by weight of aluminium at 400° C., and intersecting the eutectic line (436° C.) at the point corresponding with 12·6% aluminium by weight.

OBSERVATIONS ON THE PRESSURE OF FLUIDITY OF ANNEALED METALS.

Several points have arisen in connection with the plastic flow of ductile metals at high temperatures and room temperatures which are discussed by Dr. Hugh O'Neill and H. Greenwood in a paper presented. They refer particularly to the correlation of results obtained from compression, extrusion, indentation, and tensile tests, together with a consideration of flow effects in wire drawing.

The pressure of fluidity at room temperatures has been designated as the stress at which a loaded rigid punch continuously penetrates a block of ductile metal. Examination of such a partly-punched specimen by hardness tests after sectioning, reveals that the most highly strained regions have a (Meyer) ball index value of $n = 2{\cdot}0$ and a resistance to indentation equal to the pressure of fluidity. The value of the latter for a given specimen can therefore be determined by a cone or ball test after cold-working the material to the greatest possible extent by rolling. Furthermore, it appears that the minimum pressure required to extrude a metal through a die under certain conditions is equal to the pressure of fluidity, and very roughly equal (in most cases) to twice the Brinell number of the annealed metal.

The suggestion is made that the condition of "critical plasticity" observed by Tresca, Kick, Coe, and others, in

the course of compression tests, corresponds with the condition of "necking" in tensile tests. "Necking" commences at the point of maximum *load*, and tensile diagrams on Stead's principle indicate that the true *stress* on the section from this point (Pm) to that of fracture, has a linear relation to the decreasing diameter of the test-piece. Extrapolation then gives a stress (P*a*) at which theoretically the diameter would be reduced to zero by tensile straining. The available experimental evidence suggests that approximately: P*a* = 3Pm = the pressure of fluidity. Tensile, compression, indentation, and punching tests have thus all been related to the pressure of fluidity.

1 mm. ball tests have been made on annealed metal wires, and on the same specimens after heavy cold-rolling. In this way their pressures of fluidity were determined. The minimum stress required to draw the wires at a speed of 0·001 in. per min. through tungsten carbide dies giving 20% reduction of area was then measured. The pressures of fluidity prove to be about twenty-five times the magnitude of the minimum drawing stresses for these conditions, but if the wires are placed in a series of increasing values for each of these two tests, then the sequence in each series is the same.

THE TESTING OF CASTINGS.

The testing of castings presents many difficult problems which are of importance both to the founder and to the engineer. At the present time the whole question is of particular interest, because it has been the subject of much discussion both in connection with the proposed revision of certain British Standard Specifications and also in relation to the testing of cast iron. The latter question formed the subject of a particularly active discussion at the Zürich Congress of the International Association for Testing Materials. No apology is required for including the subject of cast iron in a discussion on the testing of castings, since the problems are, in many respects, identical. The Council considered that a general discussion of the subject at a meeting of the Institute of Metals would prove helpful to all concerned with these questions, since the manufacturer of castings, the user of castings, the scientific investigator, and those engaged professionally in testing are all interested.

The opening paper on the subject was presented by Dr. Walter Rosenhain, in which was summarised some of the principal points under discussion in regard to the testing of castings. Reference was made to the purposes for which tests are carried out, including reception or specification testing, control testing, and testing for the purpose of investigation. Attention is confined to the first two types of testing. Ideal methods of non-destructive testing being as yet unavailable, the application of the usual mechanical tests to castings is considered. The use of actual castings, or pieces cut from them for such tests, or the alternative use of specially cast test-bars, is considered in view of the fact that the properties of castings frequently vary from place to place in the same piece. The author favours the adoption of a separately cast test-piece, the use of small samples cut from actual castings being reserved for investigatory purposes. The use of chill-cast and sand-cast test-bars is discussed with special reference to the forthcoming adoption of a standardised sand-cast test-bar for the light alloys of aluminium. Reference is also made to the difficulty of determining small percentage elongations; and the author's suggestion that the practice followed in cast-iron testing of using bending tests in which deflection is measured as a means of testing ductility, is described. Reference is also made to the discussion on the testing of cast iron, which took place at the Zürich Congress of the New International Association for Testing Materials; and the author's summary of that discussion—prepared by him as chairman—which is given as an appendix to the paper, concludes with the following paragraph:—

"The position may be summed up briefly by saying that, in the opinion of the great majority of those who took part in the discussion at Zürich, the use of a separately cast test-bar, to be tested in tension and bending, is to be regarded as satisfactory and sufficient for the majority of industrial purposes, but that for the exploration of the properties of various parts of castings, and for the study of variations from one casting to another of the same type, and also for the investigation of castings which have failed in service, the small test-piece, cut from the casting itself, should be adopted."

Symposium on the Effect of Temperature on the Properties of Metals.

A further step in the progress of information respecting the high-temperature properties of metals was made as a result of the joint technical meeting held by the American Society of Mechanical Engineers and the American Society of Testing Materials, at which the available data on the subject was presented and discussed. A novel method was adopted in presenting the papers. They were preprinted and distributed well in advance of the meeting, so that those interested could digest them and prepare their discussions. An unusual amount of discussion caused a departure from the customary method of conducting technical sessions, and the papers were not presented by the authors, but were summarised by Messrs. L. W. Spring and H. J. French, members of the Joint Research Committee on the Effect of Temperature on the Properties of Metals. The papers and discussion are presented in this present volume.

The book contains the twenty-seven papers presented, which comprise compilations of data from many sources. It has been divided into two general sections, one dealing with "Engineering Trends and Requirements for Metals at High and Low Temperatures," the other with the "Properties of Available Metals for High- and Low-temperature Service."

Within the engineering fields covered, the thirty-eight authors, who prepared the papers, have had the task of summarising the information contained in the extensive literature, of valuing it critically, and of adding unpublished information. Not only are the papers of interest, both as to the data presented and their value, but the discussions which comprise more than 200 pages of the finished book have added much in further unpublished information and valuable comment.

Steps have been taken to make the book a ready reference volume, both in respect to specific and general topics relating to temperature effect on metals. A specially prepared introduction has been written which gives a brief history of the events leading up to the presentation of the work, and summarises the more important points of the papers. For those who may wish to delve into the great mass of data in the book, there is an extensive subject index and an author index. A bibliography of 600 annotated references is also included which covers the period April 1, 1930–1931.

The book, published jointly by the A.S.M.E. and A.S.T.M., may be ordered through the headquarters of either Society. It is bound in blue cloth, 6 in. by 9 in.

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Personal.

Mr. C. E. Taylor, chief engineer of the Electric Furnace Co. Ltd., 17, Victoria Street, London, S.W., who has been associated with this company for over fifteen years, has been appointed a Director.

Refractory Materials

Fireclay Bricks

By Colin Presswood, B.A., F.G.S.

Authentic reports of service given by refactories under practical conditions are valuable and more important than technical data. Some factors involved in the use of firebricks are discussed.

THE term "firebricks," which can justly be applied to all types of heat-resisting bricks, is often taken to mean fireclay bricks only. A good deal of confusion is avoided if the term is used only in its wider sense, and is prefaced by another descriptive name. One should, therefore, refer to silica firebricks, chrome firebricks, fireclay firebricks. Alternatively, one may speak of silica bricks, chrome bricks, fireclay bricks (or of clay firebricks), the term "firebricks" never being used to designate any one type.

Fireclay bricks, the subject of this article, may be grouped into many types with distinct qualities. The group itself has been defined as follows. (*a*) In the "Standard Specifications for Refractory Materials for Gas-retorts" (1925)[1]: "Goods made from fireclay containing approximately not more than 70% of silica. It is known, however, that there are, in certain areas, fireclays containing as much as 80% silica, and goods made from such clays shall be considered to conform to this specification if they pass the tests herein specified."

This specification recognises two grades of fireclay bricks:—No. 1 grade, which shows no signs of fusion when heated to a temperature of not less than Seger cone 30 (about 1,670° C.); No. 2 grade, which shows no signs of fusion when heated to a temperature of not less than Seger cone 26 (about 1,580° C.).

There follows a specification of rate of heating, atmosphere, etc. (*b*) In the Tentative Standards Definitions of the A.S.T.M.[2]—"Clay firebrick" (silica content less than 70%): (1) High-heat duty brick, P.C.E.[3] not lower than that of Standard cone 31 (about 1,680° C.); (2) intermediate-heat duty brick, P.C.E., etc., Cone 28 (about 1,615° C.); (3) moderate-heat duty brick, P.C.E., etc., cone 26 (about 1,595° C.); (4) low-heat duty brick, P.C.E., etc., cone 19 (about 1,520° C.).

The importance of careful definition (especially in the absence of specifications) cannot be too highly stressed. Thus an order recently placed asked for silica bricks. These were sent and used, with disastrous results owing to spalling. Inquiry showed that the bricks required—and previously used successfully—were high-quality Scottish fireclay material.

The wide variation in quality of material included in the generic term "fireclay bricks" is illustrated by the above definitions, and the user will find similar variation if he studies the technical data which he should obtain from his suppliers. Conditions in the furnaces, to be withstood by bricks of this class, also vary considerably, and serious failure results from ordering "fireclay bricks" without further definition.[4]

Whilst, in general, the price of bricks of this type is roughly proportional to quality, the relationship is by no means close, and careful study of properties of bricks of the same price will be well repaid.

It is impossible here to name all the metallurgical processes in which fireclay bricks are used, the applications being more numerous than the qualities. Bricks of this class are used for low-temperature furnaces, for a backing for higher-quality, special refractories, and for direct exposure to severe conditions.

Important as are technical data they are by no means conclusive, and must not be applied too rigidly. Far more valuable are authentic reports of service given under practical conditions, provided that the reports state these conditions. Our knowledge of the science of refractories and of the factors involved in their use is still inadequate. Plant reports are valuable in those cases where bricks made apparently from the same clay, by the same process, differ in the service they give. Chemical analysis alone does not suffice, since the manufacturing process can affect the properties of bricks moulded from the same clay.

Illustration of this point is found in a consideration of the amount of "grog" (or chamotte of pre-calcined clay) used by the manufacturer in his brick mixture.[5] Bricks incorporating 75% and upwards of grog are a relatively new development, and will be described specially in a later article under "chamotte" bricks. The amount of grog and its quality indicate the extent to which the brick has been "heat-treated" in manufacture, a point which is important, since many clays increase in refractoriness after being calcined to high temperature.

There is evidence that fireclay bricks hitherto unsuitable for very high-temperature work are, after suitable treatment in manufacture, capable of use in exposed positions in steel-melting furnaces.

Characteristics of Fireclay Bricks.

In a short article one must perforce use generalisations in describing the properties of any class of firebricks. Such generalisations are useful if it be recognised that they have restricted application.

Chemical Analysis.—The refractory constituent is pure clay, the mineralogy of which is the subject of research.[6] Conventionally the mineral is regarded as Kaolinite, —Al_2O_3, 2 SiO_2, 2 H_2O,—which loses the combined water when heated and would yield a brick whose composition is approximately 54% of SiO_2 and 46% Al_2O_3. The minerals produced by this heat-treatment are important in affecting the quality of the brick,[7] and the value of fireclay bricks may to some extent be appraised by a consideration of the tendeney to form the mineral Mullite (3 Al_2O_3, 2 SiO_2) in burning and in use.

Kaolin, or china clay, which is available in large quantities, and in pure condition, is used for the manufacture of a brick of high quality. Kaolin bricks are more commonly used in the U.S.A. than in this country, and have been useful in high-temperature boiler work. They are a speciality worthy of special description.

Some clays comprise natural mixtures of kaolinite with alumina in one form or another, and the bricks made from them should be described rather as "aluminous" or

REFERENCES.

1 Published by the Institution of Gas Engineers, 28, Grosvenor Gardens, Westminster.

2 *Vide Journal of American Ceramic Society* (*J.A.C.S.*), Vol. 11, No. 6, June, 1928, wherein appear some standards of the American Society for Testing Materials (A.S.T.M.)

3 P. C. E. See METALLURGIA, December, 1929, p. 81. Note that American cones are not quite the same as English. Note also wording of the test. For further details and other tests on the various grades, see references 1 and 2.

4 See METALLURGIA, November, 1929, p. 15, *re* Selection.

5 See Bulletins of Brit. Refract. Research Association, papers by Rees and Hugill. These publications are available to members only. Both manufacturers and users may join. Secretarial offices, Drayton House, Gordon Street, W.C. 1.

6 See (*a*) *J.A.C.S.*, 13, 151, 1930. Ross and Kerr.

(*b*) "Reports of Progress of Applied Chemistry," published yearly by Soc. of Chem. Industry, Section on Refractories and Ceramics. (Recs.) References to work on this subject are given.

(*c*) *J.A.C.S.*, Vol 9, No. 1, January, 1926. "Mineralogy of Clay," "Rational Analysis."

7 See—(*a*) Trans. Engl. Cer. Soc., 1927-8. Vol. 27, Pt. iv., p. 299. Hyslop and Rooksby.

(*b*) *J.A.C.S.*, 11, 829, 1928. McVay and Thompson.

(*c*) *J.A.C.S.*, 8, 1925, p. 296. Navias.

"bauxitic" bricks, than as fireclay bricks. We may regard as "fireclay" those mixtures of silica, fluxing minerals, and kaolinite, ranging from pure kaolin to a mixture with 75% total silica (combined and "free"). Mixtures, natural and artificial, showing 75% to 92% total silica, produce bricks falling into the "siliceous" class.

The brick containing 75% total silica, mentioned above, and comprising a mixture of kaolin (pure calcined) with pure silica would contain approximately 53·8% kaolin (calcined) and 46·2% silica. An analysis showing the percentages of various minerals present is known as the mineral or rational analysis, and may be calculated from the proximate analysis, which shows the percentages of the various oxides.[8] Rational analyses are always calculated and apply usually to the clays from which bricks are made. In the above case, for instance, it is not strictly correct to refer to 53·8% calcined kaolin, since in the actual brick this probably takes the form of mullite plus siliceous glass.

If, however, a proximate analysis shows no oxides other than silica and alumina, and the latter is in excess of 46%, it is customary to regard the clay from which the brick was made as containing free alumina. If, however, the usual fluxing oxides, such as FeO, Fe_2O_3, CaO, MgO, Na_2O, K_2O, TiO_2, be present, the silica and alumina must first be allocated by calculation, to form from these oxides the minerals in which they are present and the balance of SiO_2 and Al_2O_3 is reduced to the kaolinite molecule when any excess of one or the other becomes apparent.

It is difficult, therefore, to state whether a brick showing, say, 5% less than 46% Al_2O_3 contains free alumina or not until the rational analysis has been calculated.

Such investigation may seem tedious, but is valuable. Nowadays the presence of "free" alumina in bricks is being valued, and the probable behaviour of the brick in service is being foretold by consideration of mineralogical analyses. In other words, fireclays approximating to kaolinite or to mixtures of this mineral with alumina are more valuable than those comprising mixtures of kaolinite with silica.

The refractoriness of kaolinite is reduced by successive additions of finely ground silica until a "eutectic" proportion is reached, after which the melting point rises again. Coarse grains of silica show this effect to less extent, however, and the refractoriness of some clays may be considerably increased by addition of coarse silica particles. Mineral analyses are not commonly available. As a rough guide the permissible percentages of fluxing oxides in bricks may be stated as follows, the lower figure applying to high-grade and the higher to low-grade fireclay bricks.

Iron oxides	1·5 to 3·0%
CaO	1·0 to 2·5%
MgO	
TiO_2	Up to 5%
Na_2O	1·0 to 2·5%
K_2O	

The above are by no means rigidly specified, the permissible amount of any one oxide varying with the amount of others present. Some high-quality bricks show 2·5% and more of iron oxides, but the amount of free silica is low, and so is the figure for lime, magnesia, and alkalies. Titanic oxide is said not to exert fluxing action to marked extent until more than 5% is present.

There is, therefore, a wide range of mineral mixtures classified as fireclay, a large number of which are "high-heat-duty" materials. The varying composition accounts for lack of exact knowledge, and it would seem that chemical analysis should be the subject of greater attention in producing clay bricks to withstand severe conditions. Progress with silica and with magnesite bricks has been facilitated by the use in manufacture as in research of practically pure minerals in known proportions. In alumino-silica minerals the progress possible is shown by sillimanite and mullite, whether artificial or natural. Kaolin bricks point in this direction, too, and investigation of methods of purifying fireclays,[9] and of ascertaining their mineralogical constitution should be supported and encouraged.

8 See reference 6 (*c*) above.
9 F. Parentani. U.S.A. Pat 1,727,441, 10/9/'29; also Eng. Pat. 341,069, 10/9/29.

Refactoriness.

(*a*) *Cone Test.*—The P.C.E. of clay bricks varies widely, as indicated above, and for the reasons stated. The cone figures need not of necessity be high for all purposes. Thus, for steel ladle linings, there is evidence that bricks whose refractoriness is not of a very high order are better than highly refractory bricks.

(*b*) *Under Load.*—The load-bearing characteristics vary widely, too. There is a general tendency for fireclay bricks to show a wide softening range and slow collapse under load.[10] In the case of bricks containing little or no "free" silica, however (*e.g.*, the Scotch type of firebrick and kaolin bricks), the U.L. refractoriness is higher and the range of collapse much shorter.

In general, however, this class of brick is not capable of bearing heavy load at high temperatures unless some form of cooling can be applied. Thus, insulation of some furnace arches may be quite feasible if silica bricks are used, but would result in collapse of fireclay bricks if the arch were built of these.

Expansion.

(*a*) *Permanent.*—The after-expansion of clay bricks is in general negative and due to completion of volume shrinkage largely effected in manufacture. Bricks approaching "siliceous" in composition may, however, show a positive volume change depending on the amount and grain size of silica and extent of heat-treatment in manufacture. A test may, however, show a curious volume expansion known as "bloating." This is promoted by rapid heating, but is more common in the case of bricks with 3% alkalies or so. It is generally to be condemned.

In one case, however, bloating is said to be advantageous, and the brick mixture is specially blended to cause it. An American steel-ladle brick, widely used in the States and abroad, is said to "bloat" consistently in the after-expansion test, the linear increase being about 7%. In this case the bloating consequent upon sudden heating by the steel charge is said to result in a semi-fused monolithic mass with no weak joints and accounts for the success of the brick.

(*b*) *Reversible.*[11]—This is rarely more than 1% up to 1,300° C., and may be as low as ½% linear. Generally, the expansion is even and regular, any unevenness indicating the presence of free silica. Since clay bricks rarely receive the heat-treatment which it is possible to give silica bricks[12], the free silica remains as unconverted quartz, which shows the alpha to beta expansion at about 580° C. If the free silica be present in the brick as cristobalite, its presence is often discernible in the expansion curve by an unevenness at about 270° C. (alpha-beta cristobalite).

It seems preferable to have no free silica, or, alternatively, such proportions as constitute a "siliceous" brick if high quality is desired.

Effect of Atmosphere.[13]

Clay bricks, more than any, show marked lowering of refractoriness in reducing atmospheres, and the subject has been widely investigated. The effect of such gases as CO, H_2, and H_2O (as steam) is most pronounced when iron compounds are present as fluxes. The iron oxides seem particularly effective if free silica be present. The easily fusible ferrous silicates are formed.

Apart from this aspect, however, there is the most interesting case of CO reacting on clay bricks in blast-furnace linings. Following observation that blast-furnace linings were disrupted mechanically, and that the used bricks contained a deposit of carbon, it is now considered

(*Continued on page* 172.)

10 See ref. 5 and 6 (*b*) above.
11. See METALLURGIA, January 1930, p. 128.
12 Present tendency is to improve quality of bricks by higher firing temperatures in manufacture. This is facilitated by use of higher proportions of grog.
13 Trans. Engl. Cer. Soc., vol. 29, September, 1930. No. 9. Vickers.
Trans. Engl. Cer. Soc., vol. 29, November, 1930. No. 11. Swallow.

Manganese and Sulphur in Forging Steels

By Archibald Allison

Forging Steel may, and does, contain numerous inclusions, but, provided these are not too close to the surface, they may remain buried and harmless.

THE extent to which sulphur is detrimental in steel, and how far manganese is curative or preventive of detrimental effects, are matters which can only be decided by the demands made upon the steel in forging and subsequently in service. It must be confessed that many of our ideas have a foundation in tradition, and as regards steel we must turn back to the middle of the nineteenth century, when steel was exclusively a high-carbon cutting material. Notwithstanding the many convictions unjustly recorded against sulphur on the grounds of producing unsatisfactory steel, it still remains proved that in cutting steels containing 0·6% carbon and upwards a sulphur content of 0·05% is undesirable, and for real quality in tools the lower the sulphur the better. Of course, the manganese is also low in such steels.

With the advent of structural steels made by the Bessemer or open-hearth processes the position is very much different. In this country the acid Bessemer process probably produced the great bulk of the material for construction of railways and rolling stock until about 1910, and the applications of chemical analysis were not seriously made until possibly 1900.

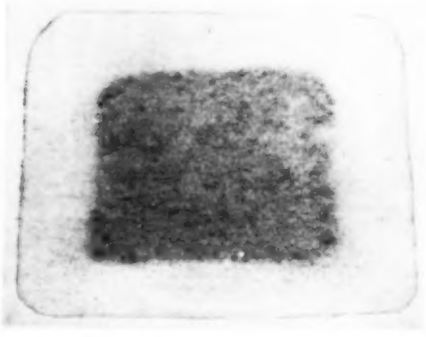


Fig. 1A. Sulphur Print of a Billet.

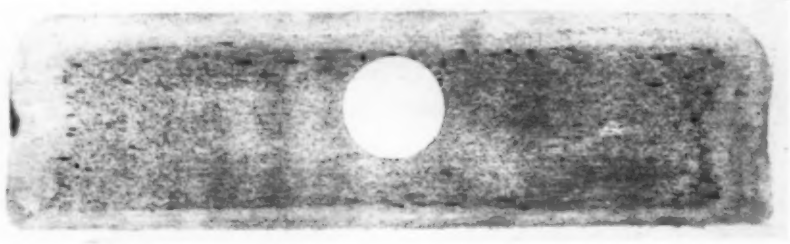


Fig. 1B. Sulphur Print of a Slab.

The steel was made and used largely upon its forgeability, and sometimes upon tensile test, and failures were few. The following analyses are taken from rails made about fifty years ago.

C.	Si.	Mn.	S.	P.
0·37	0·042	0·34	0·068	0·143
0·33	0·116	0·36	0·088	0·064
0·34	0·026	0·69	0·087	0·131
0·36	0·270	0·68	0·080	0·095
0·37	0·042	1·00	0·102	0·044
0·45	0·096	0·92	0·080	0·045

All these were acid Bessemer steel, but the last two were not put in the line, but were used for a building. The first four analyses are from rails taken up from sidings because the engineer thought that, after thirty years' life, they were better scrapped, although not worn out. At the period when these rails were made, it was the practice to hammer the ingots preparatory to rolling, at least in some works, and there is no doubt that the general structure of the steel was greatly improved thereby. The sulphur (and phosphorus) appear to have had no detrimental effect in these examples of proved forging and service.

At a similar and later period wagon tyres were made from similar Bessemer steel, and sulphur at times exceeded 0·10%. Whilst agreeing that the manganese was usually 0·75 to 0·90%, yet the forging put upon tyre blocks is a very severe test of the material, and very rarely could forging failures be attributed to sulphur. On the other hand, the larger ingots made from the open-hearth furnace naturally permitted increased segregation, and even in high-grade acid open-hearth steel, large tyres have been known to fail under test from spots of sulphur occurring in critical positions and causing interruptions of resistance to shock. It must be clearly understood, however, that the tyres failed under the falling weight test, and not in service.

There is, nevertheless, little wonder that locomotive engineers should stipulate a maximum of 0·035% sulphur and phosphorus, in view of the critical importance of the service demanded and, obviously, the lower the sulphur and phosphorus the less the liability to spots of segregation, which might lead to failure by concentration of stress. The present question is more directly concerned with permissible limits of sulphur in steels for severe forging and stamping operations, and there can be little doubt that the condition of the steel before casting and the conditions of casting are of more importance than the actual analyses. Consider the two sulphur prints shown in Fig. 1. A is the print of a billet and B of a slab, of separate casts of similar type but different conditions before casting. The sulphur print, by revealing the distribution of the sulphur, also reveals the varying distribution of accompanying elements, and the general structure of the ingot. In A the thick "case" has a sulphur content of 0·023%, whilst the "core" may have 0·056%, which is not excessive.

Some investigators have thought that the "case" in such steel always contains about 0·02% sulphur, but this is only an approximation. In billets taken from the top end of the ingot near the discard it may be possible to find 0·09% sulphur in the "core."

Now it is well recognised that tube steel is regularly made in a similar style to billet A—such material will stand any amount of forging or stamping, because of the excellent layer of solid material on the outside free from blemishes or seams. The objections of those who disapprove of such strongly heterogeneous material may be easily answered by comparing the steel with the finest wrought iron, which inevitably contains vastly more inclusions than any steel.

In slab B it will be seen that the "case" is much thinner. Correspondingly, the change in sulphur contents from outside to inside is much less pronounced. This steel also is quite reliable under severe forging. The ratio of manganese to sulphur does not seem to matter, because in neither case is the manganese higher than 0·40%.

It is well known that in this type of steel, known as "rising," the natural contraction is balanced by the

evolution of gas, which provides cavities at the roots of the crystals of the external layer. It is not, however, so well known that these cavities still persist to a large extent in the billets after rolling, although some welding undoubtedly takes place. It may be noticed that the junction of the "case" with the "core" records on the sulphur print as a series of dots indicating local concentration of sulphur. This is confirmed by taking a sulphur print longitudinally along the slab, when the dots on the transverse print are now shown as long lines. If, however, the longitudinal section is examined under the microscope, it will be found, as shown in Fig. 2, that the lines are really finely extended cavities. It may be necessary to examine several surfaces before finding a specimen in which the plane of section cuts through a cavity, and frequently it is found that the long thin cavity is slightly wavy, and the plane of section cuts the tops of the waves, producing a hit-and-miss effect, as in Fig. 3. There is also the possibility of a cavity being broken up and welded across the breaks, producing a similar appearance.

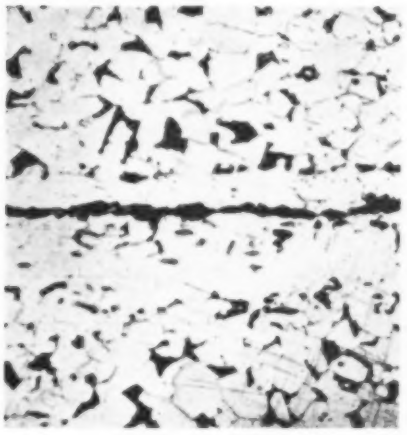


Fig. 2. ×100.

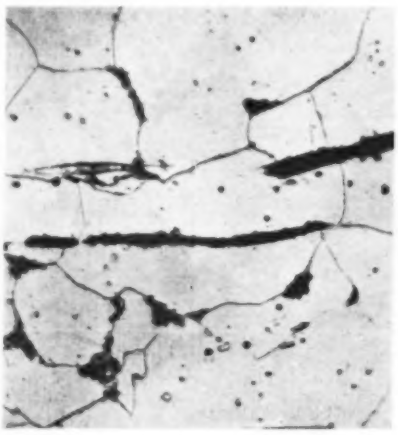


Fig. 3. ×300.

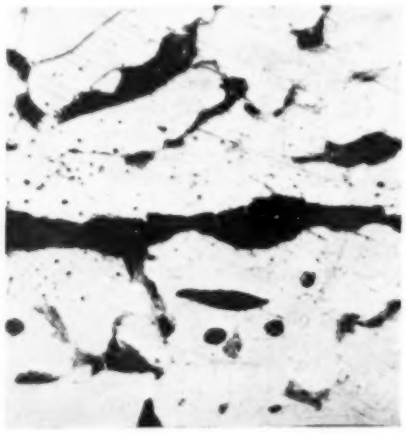


Fig. 4. ×300.

It will be seen that the thin tubular cavity is more or less filled with sulphide of manganese, some having fallen out in polishing, and the conclusion cannot be resisted that the sulphide prevents the cavities from being welded by obstructing the contact of the sides. This is illustrated by Fig. 4, which shows part of Fig. 1 at a higher magnification. This also is of importance in considering the difference between hammered and rolled blooms. In hammering, the deformation of the ingot in successive and irregular stages causes the inclusions (and also dendritic structure) to be broken up into short pieces, and welding can take place across the broken lines, so that the cavities or inclusions are rendered discontinuous and less harmful.

The even, uniform deformation of rolling, on the other hand, perpetuates the thread-like cavities or inclusions as well as the dendritic formation, with consequently less beneficial effect as indicated above. A further deduction is that possibly the manganese sulphide crystals fall out of solution whilst the metal is still pasty, and act as nuclei to start the liberation of gas. Now if the steel is cast in such a manner that there are blowholes near the surface of the ingot, when the ingots are rolled into blooms or billets, there may be rokes or seams apparent on the surface of the material. These may scale off in subsequent re-heatings, or, if buried just under the skin, may be revealed by those processes. Since a fairly high manganese is required to remove oxygen from molten steel, it follows that high manganese usually means freedom from rokes, and increased forgeability.

The sulphur in steel cast solid is distributed fairly uniformly through the mass, and cannot be blamed if the manganese was insufficient to deal with the oxygen in the molten condition, or if the steel was not correctly cast. In any case, an up-ending test is useful for determining whether or not apparent surface defects will produce unsound forgings or stampings, or whether inclusions just under the skin in apparently sound steel will break through in subsequent working.

In view of all the known facts, steel may and does contain numerous inclusions, and provided that these are not too close to the surface, they may remain buried and harmless. At all events, it seems to be a justifiable conclusion that if steel will stand the severe stamping or cold working to which it is often submitted, it will be all right in service, and, further, that sulphur is not to be so easily blamed for many forging failures.

Refractory Materials.

(*Continued from page* 170.)

that at moderate temperatures (300° to 700° C.) CO is "auto-catalysed" in the presence of ferric oxide as follows:—

$$2\,CO = CO_2 + C.$$

The carbon being deposited in the pores of the bricks.[14]

The effect can be reduced by hard burning, by the use of clays low in iron, and, more economically it seems, by correct blending and burning, in which the iron oxides are induced to form ternary or quarternary compounds which do not act as catalysts.

To realise the sensitivity of fireclay bricks to CO, H_2, and H_2O (at high temperatures) is to avoid disaster, and where such atmospheres are essential a suitable grade of brick should be used.

Such properties as abrasive resistance, density, conductivity (thermal and electrical), and spalling resistance vary widely, and need to be considered in relation to the conditions under which the bricks will be used. The properties of burnt fireclay itself—*i.e.*, apart from its constitution as a brick—are: Moderate hardness and resistance to abrasion: poor conductivity for heat (but appreciable in the light of heat losses through furnace walls): good electrical resistance: moderate spalling resistance.

In brick form the porosity may vary from 5% (vitrified "blue" firebrick, not highly refractory, but good for resisting abrasion—*e.g.*, pre-sintering zone of cement kilns, and floors of annealing ovens) up to 70%. (Clay insulating brick.) The thermal conductivity varies largely with porosity, and may be only slightly higher than that of diatomaceous earth bricks (*i.e.*, in the case of the clay insulating brick), or in the case of fireclay bricks, as such may vary from 4 to 10 times that of the diatomite brick.

The spalling resistance varies widely. Thus, one clay brick (incidentally, with high grog content, and over 40% alumina) withstood over 30 heatings and quenchings without cracking. Others crack after two or three quenchings.

14 Trans. Cer. Soc., June, 1929, vol. 28, No. 6. Hubbard and Rees. Trans. Cer. Soc., December, 1930, vol. 29, No. 12, p. 371.

Developments in Non-Ferrous Metal Rolling Mills*

By L. Wiess.

The development of non-ferrous metal rolling mills is described, and improvements due to the demand for very thin material referred to. It is shown that although it has long been known that thin material could only be produced economically with small-diameter rolls, the knowledge could not be usefully applied until suitable roller bearings had been evolved. Different types of multiple-roll mills are described and the extensive rolling possibilities with small-diameter rolls explained by reference to the processes in the rolling space. Reference is also made to the very high pressures occurring in the roll-housings, and the need for keeping watch on these in order to prevent damage to the costly roller bearings. On the basis of experiments it is shown that hardening of the supporting rolls of multiple-roll mills is unnecessary and dangerous.

ROLLING mills for non-ferrous metals form but a narrowly limited area of the wide field of the rolling-mill system, as the extrusion process is so extensively used for the production of profile products (sections). In the main, hot rolling is used for plates, sheet, and wire, and cold rolling for sheet and strip.

Development in Rolling-mill Construction.

So far as hot rolling is concerned developments have, on the whole, followed the same lines as have those in steel mills. In many cases the same appliances could be used: on the other hand, large and costly plant cannot be economically employed on non-ferrous metals owing to the restricted market.

The knowledge that brass for pressings could be hot rolled within a limited temperature range led to a special development in the hot rolling of sheets. The three-high mill is best suited to the rolling of the thickest possible plates down to about 4 mm. in minimum time. The usual Lauth's Trio is used, as are also mills with three driven rolls of equal size. At the same time the setting devices have been improved, in order to give the greatest possible regularity in thickness. Separate manually operated setting devices are therefore provided for the individual spindles.

Whilst general development in rolling-mill organisation made considerable progress towards the end of the last century as regards appropriate construction and workshop equipment, the last ten years have brought a high degree of perfection in strip mills for cold rolling by the use of every improvement in machine construction and electrical technique. There is, nowadays, no single part of the so-called "cold-rolling machine" which is not a working member.

Even before the Great War it was realised in America that very wide strip of exact thickness was required for the production of welded tubes. At the same time efforts were made to produce commercial sheets from endless strip, as this method of production was obviously most economical, and there was a demand, both in Europe and in the United States, for wider and wider accurately cold-rolled strip.

Although Lauth's patent—dating from 1864—covers not only the well-known three-high mill but also four-high and cluster mills, in isolated cases cluster mills covered by other patents were erected. It was known that greater reductions were possible with small-diameter rolls, but as the working rolls were not driven direct, but by the friction of the supporting rolls, any economy due to the smaller working rolls was nullified by the losses due to the excessive friction in the plain bearings of the supporting rolls. This may well be the reason why cluster mills had not been adopted to any extent until recently, but had apparently been forgotten.

However, owing more particularly to rapid developments in motor-car construction, roller bearings came into general use, and a very satisfactory roller bearing suitable for heavy pressures was evolved, though its incorporation in hot-rolling mills was not general. Sometimes the bearings could not be made sufficiently large with the existing housing: or it was not possible with the hot-rolling mill to keep the heating effect within the necessary limits, and finally, incorporation of the bearings was an expensive matter.

The urgent demand for wide strip recalled the cluster mill to mind, and, on the basis of previous experience, the supporting rolls were provided with roller bearings. As watercooling of the rolls is the general practice in cold rolling, heating of the bearings could be kept within the desired limits, and the much greater diameter of the supporting rolls, as compared with the working rolls, allowed enough space for the introduction of roller bearings sufficiently large to sustain heavy pressures and to have a satisfactory life. This development originated in America about ten years ago and was quickly copied in Germany.

Lauth's three-high mill has also been built as a cold-rolling mill, sometimes in the usual manner, sometimes with roller bearings for the two large rolls and a considerable reduction in the diameter of the middle roll. In this case only the latter is driven, and the journals thereon must carry the whole turning moment (Fig 1).

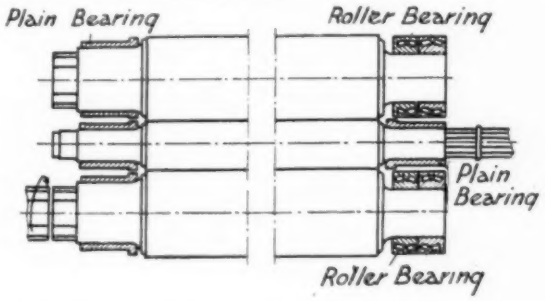


Fig. 1.—Three-high mill with plain and roller bearings.

Four-high and Cluster Mills.

The four-high mill will be dealt with mainly on the basis of actual experience. The question of whether the centres of the four rolls should lie in a vertical line, or whether it is better practice to have the working rolls horizontally displaced with reference to the supporting rolls (see Fig. 2), has frequently been discussed. Further, there is a difference of opinion as to whether displacement should be towards the entry or the exit side.

With a reversible mill displacement of the rolls is not easily carried out, and placing the roll centres in the same vertical plane causes no trouble, perfectly regular thickness being obtainable over the whole width of a strip more than 600 mm. wide. This seems to show that displacement is unnecessary. If, in the case of a non-reversible mill, it is desired to displace the rolls, the displacement must be on the side opposite to that on which horizontal distortion is to be expected, that is, on the exit side. The journals of

* Translated by I. Boodson, from "Die neuere Entwicklung der Walzwerke fur Nichteisenmetalle." *Zeitsch. f. Metallkunde*, March, 1931, p. 73 (with the permission of the VDI-Verlag and the author).

the driven working rolls are supported in the rolling direction, and distortion takes place in the opposite direction.

Displacement of the working rolls is, however, not only unnecessary but has always an accompanying and weighty disadvantage. The larger four-high mills are fitted with motor drive for the setting device. When thin strip is being rolled, the rolls must bear so heavily on each other

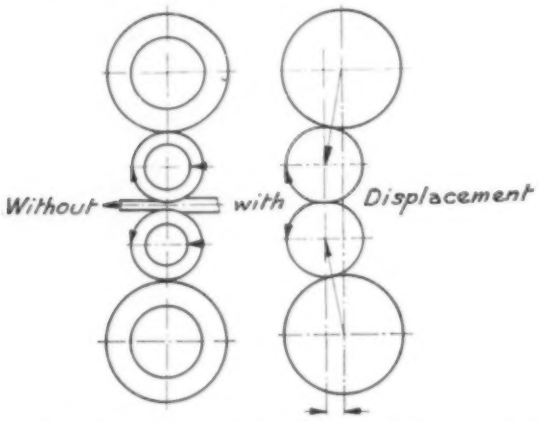


Fig. 2.—Four-high mill with and without displacement of working rolls.

that considerable elastic deformation occurs. This pressure can easily exceed the desired amount, and then seeks to force the working rolls in the direction of the displacement, thus causing distortion. With larger rolling thicknesses this horizontal component may exceed the actual rolling pressure.

Certain noteworthy experiments described in the *Kugellagerzeitschrift*, 1930, No. 3, p. 61, show how great this elastic deformation may be. Iron strip was compressed to a definite end thickness between two rolls 210 mm. (8¼ in.) in diameter. From the least and greatest strip thicknesses, and the length of the deformation stretch, the radius of the elastically deformed rolls could be determined. With end thicknesses of less than 0·5 mm., the flattening of the rolls was shown to correspond to a doubling of the diameter of the unloaded rolls.

The Research Institute also carried out a praiseworthy task in determining the permissible compressive stresses for hardened steel rolls.

The following example shows how high the stresses may be :—When in a four-high mill, with working rolls 275 mm. diameter and 800 mm. wide, the load on the rolls is 300,000 kg., as is the case in practice, the compressive stress $\sigma_{max.}$, calculated in accordance with Hertz's method, works out at 13,800 kg./cm.², and the breadth of the surface of contact at 3·45 mm.

The spherical arrangement of the roller bearings allows of the uptake of the axial pressure without clamps, owing to the distortion of the journal. The water-cooled plain bearings on the working rolls can likewise follow the horizontal distortion, and can be easily regulated. It is perhaps hardly necessary to state that the setting device must be capable of giving exactly simultaneous, as well as individual, movement of the rolls under compression in a simple and speedy manner.

For very hard material the cluster mill is to be preferred, as horizontal distortion on either side is prevented by the placing of the working rolls between the supporting rolls. The ratio between the diameters of the working and the supporting rolls in this mill cannot be varied at will, as will be obvious from Fig. 3.

Two-high mills have recently been fitted with roller bearings, in that the roll journals are supported by two rollers running in roller bearings (Fig. 4). This arrangement, however, gives no support to the roll body. Further, four-high mills have recently been built with laterally displaced working rolls receiving oblique support from driven supporting rolls (Fig. 5). Lateral support is thus actually obtained on both sides, and horizontal distortion in either direction is prevented; in addition, one is not limited in the choice of ratio between the diameters of the working and supporting rolls, as in the case of the cluster mill.

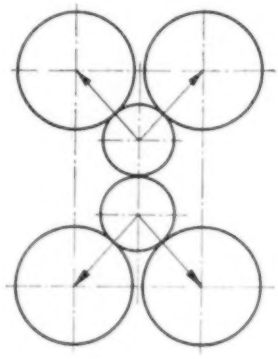


Fig. 3.—Cluster mill.

The coilers and brakes used for maintaining the rolling direction must be easily regulated to the required tension, and should not be misused.

Numerous experiments with the four-high mill, having working rolls 275 mm. diameter, supporting rolls 550 mm. diameter, and width of body 800 mm., proved how great the difference in power consumption, as compared with plain bearings, can be. For the comparison it was assumed that the supporting rolls were fitted with plain bearings, instead of roller bearings. As compared with the results with roller bearings, the results with plain bearings for the supporting rolls gave practically double the loss. On the average the loss in the experiments with roller bearings amounted to 27% of the useful power at the roll circumference. The calculation for plain bearings gave the loss as 53% of the useful power. If the same rolling were carried out on a two-high mill with rolls 550 mm. diameter, the power consumption, assuming the big reductions were possible, would be two-and-a-half times as high.

The friction losses with roller bearings must be very small, as even during the longest pass scarcely any variation in the uptake of power is observable, whereas with plain bearings the heating and uptake of power increase with the length of the pass. Further, it is not possible to give, on a two-high mill, with its necessarily larger roll diameters, such heavy passes as can be given on a cluster mill with its smaller working rolls, with which considerably fewer passes are required for the same reduction.

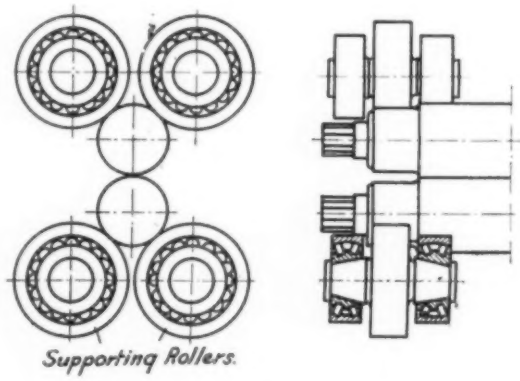


Fig. 4.—Two-high mill with roller bearings.

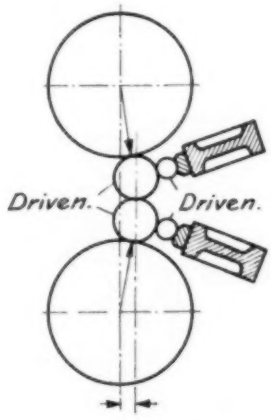


Fig. 5.—Four-high mill with lateral support.

The reason for the lower expenditure of power with small, as compared with large, diameter rolls may well be discussed here.

The operator says that small rolls "cut" better. Frequently it is assumed that the lower power consumption with small rolls is linked up with lower roll pressure. It is known that with equal reductions the static roll pressure is proportional to the square root of the roll diameter. It may easily be shown, however, that the force at the roll circumference is independent of the roll diameter, and is dependent only on the reduction and the mean specific resistance to deformation, so long as the resulting roll pressure can be regarded as acting at the middle point of the deformation length, Fig. 6.

According to the author's latest experiments it is much more a question of complicated slip processes in the rolling space; the increase in the deformation length, which is proportional to the square root of the diameter, interferes with these processes and may finally make rolling impossible. Thus, copper strip 4 mm. thick can be rolled down to 2·4 mm., a reduction of 40%, with rolls 275 mm. diameter without a break, whereas this is impossible with rolls 650 mm. diameter. An attempt was made to roll a strip from 4·7 to 3·55 mm., a 25% reduction, on a two-high mill with 650 mm. rolls. The metal stuck between the rolls and only came through gradually and jerkily, with considerable chattering of the housing. (This is more fully dealt with in the February (1931) number of the *Zeitsch. f. Metallkunde*, p. 50.)

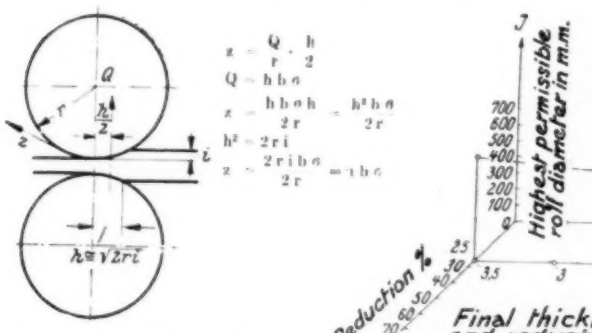


Fig. 6.—Basis for calculating roll pressures.

The relation between the roll diameter, the percentage reduction, and the thickness at exit, based on the author's experience in the rolling of copper, is shown diagrammatically in Fig. 7. The limit to the rolling possibilities is determined by the elastic deformation of the rolls, which causes a flattening of the cylindrical exterior of the rolls, and does not permit of a further reduction despite the resetting of the rolls.

In this connection it may be pointed out that the numerous experimental results with different materials, published in the previously mentioned *Kugellagerzeitschrift*, are not translatable to any desired roll diameter. Thus, copper was rolled from 1·79 to 0·71 mm., a reduction of 60%, in one pass with rolls 210 mm. diameter, this corresponding to a ratio $\frac{h^1}{r} = 0{\cdot}017$. Translated to a roll diameter of 650 mm., this gives a reduction from 5·5 to 2·2 mm., a pass which, as already pointed out, is impossible.

The far-reaching possibility of slip in the rolling space with small roll diameters is shown by the following observation:—

A copper strip 600 mm. wide was rolled from 2·56 to 0·27 mm. in six passes on a four-high mill with working rolls 275 mm. diameter; after each pass test pieces were taken along and across the strip. Whereas, in the original annealed state, the longitudinal tensile strength was about 2% higher than the traverse, after the fourth pass the transverse tensile strength was 12% higher than the longitudinal. The conclusion drawn by the author is that the strip flowed transversely and after leaving the rolls sprang back owing to its elasticity. After the last pass the increase in the transverse strength fell to 7%, as with reduced thickness the transverse flow was hindered to a greater extent.

Further, the investigations of Siebel and Pomp have shown that in the cold rolling of copper the resistance to deformation may amount to 100 kg./mm.², referred to the calculated area under pressure, and that the rise in pressure is proportional to the reduction. The author's rolling experiments have shown that in certain circumstances the increase in pressure in the rolling space may amount to two or three times the static flow pressure. If the rolls be drawn apart an equalisation of pressure takes place—*i.e.*, the pressure falls to the static flow pressure, and a corresponding impression is left on the strip. Hence the conditions of the rolling process cannot be reproduced in static compression experiments.

Final Thickness, mm.		3.5	2.5	2	1.5	1	0.75	0.5	0.2	0.1
25% Reduction	Roll Diameters	650	550	510	440	350	300	250	190	170
30% ..	.. ..	—	450	400	360	300	280	240	180	160
40% ..	.. ..	—	330	300	270	240	220	190	150	140
50% ..	.. ..	—	—	260	240	220	200	180	140	130
60% ..	.. ..	—	—	—	220	190	180	160	125	110
70% ..	.. ..	—	—	—	—	—	140	130	100	90

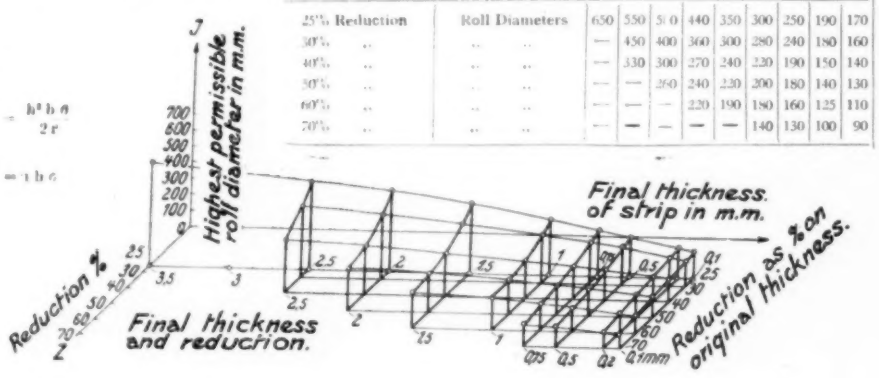

Highest permissible roll diameter in m.m.
Final thickness of strip in m.m.
Reduction %
Final thickness and reduction.
Reduction as % on original thickness.

Fig. 7.—Permissible roll diameters of different final thicknesses and reductions. Material—copper.

It is now generally known that the life of the expensive roller bearing is dependent on the average load and is inversely proportional to P^3, approximately. It is consequently very necessary to be able to learn what rolling pressures arise, in order to maintain the load within the most economical limits, and to determine the permissible roll diameter. For this reason the author regrets that lack of means has made it impossible for the management of his works to provide pressure-measuring appliances.

It may be said that the solution of these questions is a matter for the research institutions, but, in the author's opinion the manysidedness of the problem calls for very extensive experiments such as cannot, for various reasons, be carried out by these institutions. Numerous works trials are necessary to confirm the conclusions of the research institutions. The maintenance of such expensive plant as the cluster mill is, however, so important a matter that pressure-measuring appliances should be provided, despite the need for economy.

Roll Fractures.

In conclusion, a matter which has caused a certain amount of uneasiness among owners of cluster mills may be considered. With supporting rolls of large diameter roll fractures have frequently occurred in mills of both home and foreign origin. Both working and supporting rolls were hardened, having scleroscope hardnesses between 90 and 100. To the author's knowledge the hardening of such large rolls is very difficult, and scarcely possible without causing considerable stresses; the fact that hardened rolls of large diameter frequently crack before being taken into use is proof of this. If two rolls of approximately the same hardness run on each other for a long time the

differences in hardness in the larger roll will increase to such an extent that, sooner or later, fracture will occur. When the supporting roll breaks the working roll will likewise break, provided, of course, that the break occurs under rolling pressure, since the moment of resistance of the working roll is only about one-eighth that of the supporting rolls.

In the roll fractures observed by the author the cracks were always longitudinal with numerous transverse fissures. Hence, it is concluded that hardness stresses, are the cause of the fractures in the supporting rolls and the question arises—Is it necessary to harden these rolls? The extent of the distortion is dependent only on the modulus of elasticity, which is not essentially altered by hardening. Hence the rolling result cannot be influenced by the use of unhardened rolls.

On the author's advice a mill was fitted with an unhardened supporting roll, and the rolling was as accurate as with the hardened roll. As a result the second supporting roll was replaced by an unhardened roll. This knowledge should make the use of even wider rolls possible, whilst the phenomena associated with fractures suggest the use of even softer supporting rolls. The chilled-iron rolls of an American cluster mill also cracked, and were replaced by steel rolls.

Cluster mills, arranged one behind the other, are used, both in America and Germany, as a continuous train for hot as well as cold rolling.

Summary.

In connection with the development of fine rolling by the use of multiple-roll mills having working rolls of small diameter, it is shown that the extensive rolling possibilities thereby made available are due to more satisfactory slip processes in the rolling space, these processes being adversely affected by the use of larger diameters. The limitation to the reduction in the roll diameter is referred to, in so far as it is shown that, when the roll pressure exceeds a certain amount, flattening of the surface of the rolls under pressure occurs and the possibility of slip is thereby limited. Experience on the hardness of supporting and working rolls is also mentioned.

Reviews of Current Literature.

Foundations and Methods of Chemical Analysis by the Emission Spectrum.

THIS work embraces a comprehensive treatment of quantitative spectrographic analysis from its origin to recent investigations. Much of the text is devoted to the conclusions and results obtained by the authors, which were published by them in a series of papers in the *Zeitschrift für Anorganische und Allgemeine Chemie* and in the *Zeitschrift für Metallkunde*, as well as in the *Metallwirtschaft*.

Spectrum analysis as it exists to-day provides a rapid means of determining the metallic constituents of any substance, and in this book the authors discuss the principles on which any sound method must be founded. Preference is given to the employment of the spark spectra and the condensed spark is referred to almost exclusively. The technique of analysis, using both solid electrodes and solutions, and many useful methods of procedure are described and fully illustrated. Many features are included in this book which increase its usefulness; thus, for instance, methods of selecting homologous line pairs are described; increasing the selectivity in certain cases, where, without special means, the spectrum lines would fail to appear; distinguishing between external impurities and those impurities which are actual contents of the specimen; methods of quantitative analysis are fully discussed, and the authors show that the method of comparison spectra is capable of great precision in the determination of small quantities of impurities. In addition, several "absolute" methods, which have been devised and standardised, are very fully described. The basis of these is the correlation of the equality of intensity of two lines (one due to the primary metal and the other due to the minor constituent) with percentage content of the minor constituent. It is also shown how to increase artificially the number of the internal intensity standard lines by the superposition of an auxiliary spectrum.

Adopting these methods, tables are given for the analysis of tin, lead, iron, platinum, and bismuth, containing impurities common to these metals, and since the lines of an impurity possess equal *relative* sensitivity, whatever the primary metal in which they occur, a method is described which enables the use of standard alloys of a metal with a given impurity for the determination of this impurity in another metal.

The refinement of the spectrographic method by microphotometric measurements of the intensity of the lines is discussed, and the precautions necessary for its practical application are stated, since the results obtained are not directly comparable with those obtained by visual estimations.

The last chapter gives several examples of "local analysis," taken from actual practice, such as the analysis of inclusions, metallic coatings, and the detection of segregation of impurities, and the book concludes with a discussion of the correct interpretation of spectro-analytical data and the scope of application of the spectrographic method as compared with chemical analysis.

This valuable work indicates very clearly that analysis by the emission spectrum provides new methods of investigation in connection with technical processes, and facilitates the solution of problems concerning metals which previously could not be brought within the scope of scientific control. The development of chemical analysis by this process supplies another instance of the great service which pure physical research, experimental as well as theoretical, is capable of rendering by its direct application to the practical solution of modern technical problems.

By Dr. Walter Gerlach and Dr. Eugen Schweitzer. Published by Adam Hilger, Ltd., 24, Rochester Place, Camden Road, N.W. 1. Price 12s. 6d. net; 13s. post free.

Symposium on Welding.

THE papers and discussion published in this volume embrace a Symposium on Welding held at the second regional meeting of the American Society of Testing Materials, at Pittsburg, March, 1931, in which the Pittsburg section of the American Welding Society co-operated. Two sessions were devoted to the symposium; in the first, the various welding processes, materials, and applications of the methods were discussed. The second session was devoted to inspection and testing of welding.

Special attention is paid to characteristics and interrelation of newer steel-welding processes. A classification of processes and uses is given from the function standpoint. The various methods of gas and electric-arc welding applicable to aluminium are discussed. This involves types of joints used, alloys welded, and merits of the methods. Fusion welding of high-carbon and special steels is discussed. Specifications for welding and the necessity of welding materials' standardisation are emphasised.

A major portion of the symposium treats of the testing of welds and welded products. One author discusses extensively the stethoscope method of weld testing. Magnetographic inspection and magnetic weld test meters are described, as well as other types of magnetic testing apparatus. The utilisation of X-ray equipment for welding as carried out at the Watertown Arsenal is full discussed, and its importance and value stated.

The book of 152 pages is bound in cloth. Throughout are many photographs, tables, and diagrams. Copies can be obtained from A.S.T.M. Headquarters, 1,315 Spruce Street, Philadelphia, for $1.75 each.

The Trend of X-Ray Analysis in Metallurgy

By L. Pickup, B.Sc., (Lond.)

Much Metallurgical progress has been accomplished by means of the microscope, thermal analysis and other physical methods, but many problems remain to be solved. X-Ray methods have thrown considerable light on these problems, some of which are discussed in this article.

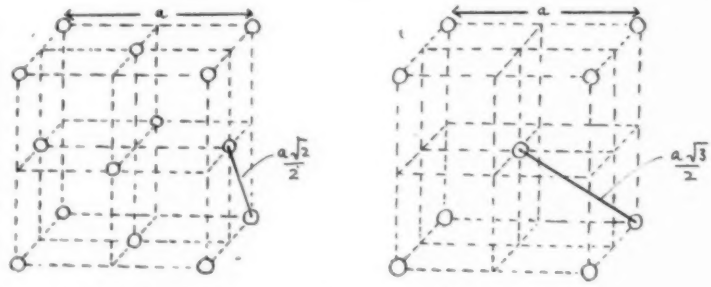
THE handling of materials was practically in the long run dependent on the relations between the atomic forces that bound atom to atom. The most direct method of examining these forces depended on the solution of the structure of the crystal in which they were exerted, because the crystalline structure was the direct outcome and manifestation of the forces. This view, expressed by Sir W. H. Bragg,[1] indicates the avenue along which the application of X-ray analysis to metallurgy is likely to be of more fundamental value than any other means hitherto applied. It is intended to show how far along this avenue work has progressed, and to show briefly from the data already available what conclusions have been made of the nature of solid solutions and the so-called " inter-metallic " compounds of metallic alloys.

The author's article, " X-rays and Metallurgy,"[2] summarised the manner in which X-rays are being applied to the study of metals, but while this work has been carried on for only a few years, enough has been done to show that a very wide and fruitful field of research has been opened up. The data collected up to the present is obviously disjointed, being spread over journals in many countries, so that practically all conclusions are tentative, pending further corroboration and experimental work. Such conclusions and theories that are already advanced are of theoretical interest, but this trend should not detract from its value to the student of metallurgy, because it is consistent with the modern school of metallurgy as compared to the old " rule-of-thumb " school, in which much fundamental and sound data were shrouded often in secrecy and tradition.

In spite of the large amount of metallurgical work done before the development of X-rays, notably by means of the microscope, thermal analysis and other physical methods, there are still many points and problems to be solved. As examples, we may cite the allotropic forms of iron, the constitution of such phases as martensite, the definition of inter-metallic compound, the true mechanism of rolling, the controversy of the phases β and β' in brass. It would seem that the means of research available were not powerful enough to solve such problems ; but while it is much too soon to predict a solution forthcoming by X-ray methods, such methods have thrown considerable light on each of the problems just mentioned. The α and δ modifications of iron have body-centred crystal units, while those of the β and γ modifications are face-centred.[3] Martensite is nearly amorphous owing to the annihilation of crystal form by the distortion during its production.[3] Rolling tends to orientate certain crystal planes in definite directions relative to the direction of rolling—that is, certain planes appear more favourable than others to such sliding movements. X-ray investigations show no crystallographic differences between the β and β^1 phases of brass, as far as size and form are concerned.

The lattice structure of nearly all the metals divides itself into two main groups—the cubic and the hexagonal,—all of which are of simple form. That a solid solution of metal A in metal B shows the lattice structure of the latter metal is suggested by the microscopic study, where the presence of metal A is not indicated at all. From X-ray analysis we now know that the form of the crystal structure of the solution is that of the solvent metal, whether the metal A has a similar structure to metal B or not. In other words, the identity of the structure of metal A is completely lost when solution occurs.

The atoms in the lattice structure are taken to have " size," which can be calculated from the lattice dimensions,



(*a*) *Face-centred.* *Fig.* 1. (*b*) *Body-centred.*

this size being taken as the distance of nearest approach. If a is taken as the lattice side, for the distance of nearest approach, we have $a\sqrt{2}/2$ and $a\sqrt{3}/2$ for the face-centred and body-centred units respectively (see Fig. 1). For hexagonal close-pack units with side a and axial ratio c, there are two distances—namely, a and $a\sqrt{\frac{c^2}{4}+\frac{1}{3}}$, as indicated in Fig. 2. Each of these distances can be regarded as the dimensions of a space inside which no other atom can penetrate. For cubic crystals, these spaces appear spherical, and for hexagonal crystals ellipsoids, though some workers have found it necessary to assign other shapes to these spaces to account for their data. But, in spite of this uncertainty as regards the space occupied by an atom, we can obtain approximate relative figures for the different atoms. Therefore, when a solute atom enters the solvent lattice, and since this lattice retains its form, the size of the lattice must change, unless the spaces occupied by the two kinds of atoms are identical. Consequently, the lattice expands when a larger atom enters, and contracts when a smaller atom enters. A comparison of the space dimensions of the atoms of copper, aluminium, and zinc will illustrate this point. Particulars of these three metals are given in the Table I.

1 Sir W. H. Bragg : Discussion. " The Crystal Structure of Steel " (Westgren and Phragmen), *J. Iron and Steel Inst.*, vol. cv., No. 1 (1922).

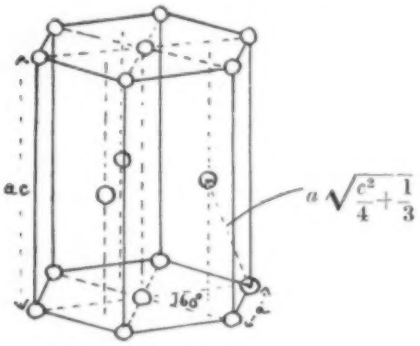
2 METALLURGIA, vol. 3, No. 15, January, 1931.

3 Westgren and Phragmen : " The Crystal Structure of Steel," *J. Iron and Steel Inst.*, vol. cv., No. 1 (1922).

TABLE I.

Metal.	Lattice Type.	Parameter.	Distance of Nearest Approach.
Copper	Face-centred cubic	$3{\cdot}608 \times 10^{-8}$ cms.	$2{\cdot}55 \times 10^{-8}$ cms.
Aluminium .	Face-centred cubic	$4{\cdot}041 \times 10^{-8}$ cms.	$2{\cdot}86 \times 10^{-8}$ cms.
Zinc	Close-pack hexagonal ..	$2{\cdot}64 \times 10^{-8}$ cms.	$2{\cdot}64 \times 10^{-8}$ cms.
	$c = 1{\cdot}86$		$2{\cdot}89 \times 10^{-8}$ cms.

It will be seen that the zinc atom is greater than the copper atom, hence solution of zinc in copper should cause an expansion of the copper lattice up to the saturation point, after which the parameter should remain constant to the limit of the α-phase (solid solution). The solution of zinc in aluminium should cause a contraction of the lattice, since the zinc atom is smaller than that of the aluminium. These deductions are fully borne out by X-ray experimental data on these systems. The changes in the solvent lattice are sometimes very small when the amount of solute required to give saturation is small, so that high precision work is essential to trace accurately the changes. The high accuracy required in X-ray analysis is now being developed. At the present, it is about of the order of 1 in 4,000. With more perfected technique, it seems probable that a new method for determining the limit of solubility (when the lattice remains constant with further additions of the solute atoms) will be evolved. Such a method would help considerably to establish more completely the positions of boundaries between certain phases in the thermal equilibrium diagrams.



Hexagonal Close-pack.
Fig. 2.

The mode of entering of a foreign atom into a lattice structure, which does not alter in form but only in size, can take place in two possible ways. It can either take a position between the atoms of the solvent—an "interstitial" solution,—or it can replace an atom of the solvent—a "substitutional" solution. The extensive work of Bain[4] on a number of solid solutions, and of McKeehan[5] on certain silver alloys, suggests that the solution is "substitutional," while Westgren and Phragmen[3] come to the conclusion that the carbon atoms in steel are located in the interstices of the iron lattice. It was the object of Owen and Preston[6] to obtain "further data regarding the structure of solid solutions, and if possible to differentiate the more easily what may be termed the 'substitutional' and the 'interstitial' atomic arrangements." Their method and results will now be summarised.

If there are N_2 atoms of a metal of atomic weight M_2 dissolved in N_1 atoms of a metal of atomic weight M_1, then the average mass associated with each point of the lattice will be—

$$M_s = \frac{N_2 M_2 + N_1 M_1}{N_1 + N_2} \quad \ldots\ldots\ldots\ldots (1)$$

for substitutional solution.

If the atoms form an interstitial solution, we have for the mean mass—

$$M_i = \frac{M_1 N_1 + M_2 N_2}{N_1}$$

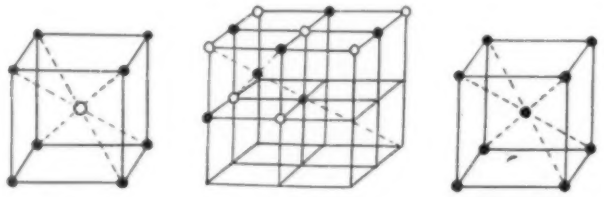
$$= M_1 + \frac{N_2}{N_1} M_2 \quad \ldots\ldots\ldots\ldots\ldots (2)$$

As has been previously shown,[2] for a face-centred lattice the unit cell is equivalent in weight to 4 M, where M is the weight of the atom. Then with parameter a and density ρ we have—

$$\rho = \frac{4\,M}{a^3} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

If the density ρ and the parameter a are determined experimentally for a face-centred solid solution of known atomic composition, a value for the mean mass can be found by using relation [3] above. This value of M, on comparison with M_s and M_i, calculated from relations [1] and [2] above respectively, will indicate the type of solution which has been formed. It was found for a range of four solutions of aluminium in copper up to 8% Al, that the value of the density in each case, assuming substitutional solution, was not greater than 0·8% of the determined density. Assuming an interstitial solution, too high a value for the density was obtained. Again, when the determined density was taken and the parameter calculated, it was found that for the 8% Al alloy the value of the parameter would be $3{\cdot}89 \times 10^{-8}$ cms. for interstitial solution, and $3{\cdot}65 \times 10^{-8}$ cms. for substitutional solution. As the latter value agrees with the experimental value $3{\cdot}649 \times 10^{-8}$ cms., this indicates that the solution is of the substitutional type.

The solution of 8% of magnesium in aluminium was also investigated. This gave a face-centred powder photograph, with a small lattice expansion. The mean value of the parameter was found to be $4{\cdot}106 \times 10^{-8}$ cms., with a possible error of 0·5%. The density was 2·57, which on the substitutional theory gives a value of $4{\cdot}10 \times 10^{-8}$ cms.



● Cu ○ Zn
CuZn

● Cu ○ Al
Cu_3Al

● Cu and Sn
Distribution at random
Cu_5Sn

Fig. 3.

for the average spacing. Interstitial solution would require a spacing of $4{\cdot}23 \times 10^{-8}$ cms. to give the observed density. Again, it was found that the solution is substitutional. Another interesting example is the introduction of aluminium into the close-pack hexagonal lattice of magnesium, since the introduction can affect independently both the side of the hexagonal base a and the axial ratio c. It was found that the aluminium atoms replace the magnesium atoms, thereby slightly decreasing the value of a, but increasing the distance between the hexagonal planes.

Copper-nickel alloys form solid solution of the substitutional type, and Vegard and Dale[7] found that the lattice dimensions of this system changed linearly with the composition. Vegard had already found such a relation for alkali halides and other pairs of chemically related salts crystallised together. The gold-copper series of alloys was found to depart from this rule, and this was later confirmed by van Arkel and Basart,[8] who found that the fifth exponent of the atomic diameter was more suitable than the first as an additive quantity. It is to be noticed that the above work has been carried out on systems formed by chemically closely-related components. Quite different conditions are met with when the components differ widely in chemical character. At the present time, enough accurate X-ray work has not been done to deduce any definite conclusions with regard to the relations of the change in lattice parameter with composition, but the great majority of solutions appear to be of the substitutional type.

4 Bain: *Chem. and Met. Eng.*, October (1921), January (1923).
5 McKeehan: *Phys. Rev.*, vol. 20, November (1922).
6 Owen and Preston: *Phys. Soc. Lond*, vol. 36, Part I., December, 1923.
7 Vegard and Dale: *Z. Kristall.*, 67, 148 (1928).
8 van Arkel and Basart: *Z. Kristall*, 68, 475 (1928).

A study of the formulæ of the so-called inter-metallic compounds immediately shows that nearly all these fall out of line with the chemical formulæ of inorganic salts. Up to the present, no established theory has been put forward to account for either these formulæ or their marked difference from those of inorganic salts. In the past, the criterion of an inter-metallic compound has been based on a deviation or an abrupt change in the progressive change of a physical property, such as electric resistance, thermal dilatation, heat of solution, and so on, with composition. The formula of the compound was then found from the composition at which such a deviation or change took place. X-ray analysis is already giving some information on the determination and structure of inter-metallic compounds, but while this is at present scanty, it would appear to suggest that some so-called " inter-metallic " compounds are more probably solid solutions, or at least modifications. Enough metallurgical research work has now been done to show that for certain alloy systems very great difficulties are present in obtaining a true stable equilibrium condition throughout a mass of alloy, so that the errors, if any, in the detection and identification of such compounds may be due rather to the unstable constitution of the alloy than to the actual methods of investigation employed. X-ray work has, for some compounds, both determined the form of crystal and the relative positions of the two kinds of atoms present. The structures of these compounds hitherto investigated appear to reduce to a relatively few types. Most alloys have an essentially face-centred, body-centred, or close-pack hexagonal basis with complicated variations.

Chemical compounds are, by definition, those in which there are constant and simple stoichiometrical proportions of their components. Therefore, inter-metallic phases of variable composition should not be called chemical compounds at all, but regarded as solid solutions.

The two chief methods of investigating the form and structure of inter-metallic compounds by X-ray analysis will now be briefly described. The investigation of the form and distribution of atoms in these compounds is usually difficult and laborious; one method is based on photographs from samples in powder form, and the other utilises the reflections from a rotating single crystal. The simplest crystal form that completely accounts for all the reflections registered is taken as the correct one. The method adopted for the analysis of powder photographs is based on graphical curves,[9] corresponding to the different possible forms of crystals, such as cubic, hexagonal, tetragonal, rhombohedral, etc., together with the body- and face-centred modifications of these types. Suitable plots are made from the photographs, and a perfect fit is found, if possible, on one of these curves. From such a fit one can find (1) the type of unit cell; (2) the Miller indices of the set of planes corresponding to each reflection recorded; and (3) the axial ratio when existent. These data enable the parameter to be determined. The parameter so determined may be one-half or perhaps twice the true value, but this ambiguity is decided by other considerations, which are not enumerated here owing to their complexity. As mentioned elsewhere,[2] the scattering power of the different atoms varies, so that when there are two kinds present this fact is used to find the relative positions of the atoms in the unit. For a type of unit cell composed of *one* kind of atom only, the relative values of the intensities of the reflections from each set of planes are generally known, so that *two* kinds of atoms forming the same type of cell will, when the scattering power of the second kind is different, show reflection lines with altered relative intensities. A study of such changes has enabled in some cases the positions of the two kinds of atoms in the unit to be determined. However, the mathematical formula on which one depends to assign positions to atoms in this manner is somewhat empirical, so that sometimes there may be a slight doubt as to the relative positions obtained by this method. An account of the mathematical analysis and the method of experiment using single crystal reflections is given in a paper by Bernal,[10] which is too lengthy and involved to attempt to give even a *resume* here. This method, however, has not been applied very much up to the present to the " inter-metallic " crystals, but application will be more general in the future, because it has marked advantages over " powder " photographs for this work. The chief of these are that no ambiguity is encountered as regards the unit size, and, secondly, crystal forms can be determined for which it is not possible to construct graphical curves, necessary for powder photograph analysis. The lack of application of this second method to the determination of metal crystal structures is no doubt due to the difficulties encountered in preparing true single crystals of the metallic phases. The development of the method of production of single crystals of pure metals will give much useful help in developing a suitable method of obtaining the crystals of phases required by this method.

As the chemist sought theories of chemical valency based on the modern theory of electron groupings, the suggestion of Hume-Rothery,[11] that the β-phases of the systems Cu-Zn, Cu-Al, and Cu-Sn should be analogous in structure because for each of these phases—with formulæ CuZn, Cu_3Al, and Cu_5Sn respectively—the ratio of valency electrons to atoms is 3 to 2, is on the same lines. X-ray analysis shows each of these phases to have a body-centred type of structure (see Fig. 3) as predicted. The lattice of the complete unit of Cu_3Al is shown in the figure, but the distribution of the atoms in a portion only is indicated to avoid confusion. The complete unit has nine copper atoms within, with alternate copper and aluminium atoms on all the outside planes of the figure, as shown in the top plane. It will be seen, further, that the relative positions of the two kinds of atoms in both Cu, Zn, and Cu_3Al have been determined, but in Cu_5Sn there appears no fixed positions for the copper and the tin atoms, except that they together form a body-centred unit, while a solution in copper of tin atoms would have produced a face-centred unit. Several binary alloys of copper, gold, and silver have been found, in which phases of this form occur at concentrations making the ratio of valency electrons to atoms about 3 to 2.

Another more complicated type of structure has been isolated, where there are usually 52 atoms in the unit cell. Such phases are formed when copper, gold, and silver are combined with zinc, cadmium—giving formulæ of the type Cu_5Zn_8, Ag_5Cd_8. In these phases there are 21 valency electrons to 13 atoms. At present no explanation is available for these particular ratio figures.

If a table of metals is prepared, based on the crystal forms, the grouping would be found to follow very closely that of the periodic table of the chemical elements; therefore, analogous crystal forms composed of a similar pair of metals are to be expected. Not many systems have been worked out completely by X-ray methods yet, but Westgren and Phragmen[12] have clearly shown the analogous structures and phases in the systems of silver-zinc, gold-zinc, and copper-zinc.

The above brief outline, quoting a few examples of X-ray analysis to problems in metallurgy, indicates that work on these lines will not only give a more precise meaning to the nature of solid solutions and inter-metallic compounds, and add to our knowledge of thermal equilibrium diagrams and their boundaries, but it will also give ultimately more fundamental views of the metallic state itself. And, further, one may predict that in the distant future, as more analogies and more similar forms and structures of metallic phases are found, laws and conditions may be deduced by means of which it may be possible to deduce accurately the whole behaviour of an alloy or a system of alloys with the aid of little, if any, actual experimental work.

9 Hull and Davey: *Phys. Rev.*, vol. xvii., No. 5, May, 1921.
10 Bernal: *Proc. Roy. Soc., Lond.*, vol. cxiii., Series A.
11 Hume-Rothery: *J. Inst. Metals*, 35, 194 (1926).
12 Westgren and Phragmen: *Phil. Mag.*, vol l., No. ccxcv., July (1925).

Some Recent Inventions.

The Production of Magnesium and Magnesium Alloy Forgings.

IN working magnesium and its alloys, it has been observed that the production of a finer grain-size may lead to pieces which may be considered as extensively orientated in respect to their mechanical properties. This is probably attributable to the hexagonal lattice structure of magnesium, the elastic limits of hexagonal crystals differing considerably according to the direction in which they are stressed. Further translation in crystals of magnesium and its alloys takes place substantially along planes parallel to one of the crystal surfaces. The result of this metallographic orientation is that the work displays varying mechanical properties in different directions and under different types of stress. This does not mean that the special orientation occurring in the mechanical properties of forgings during the shaping process represents the optimum value with reference to the stresses, and directions of stressing to which the work is subjected while in use. A new process, however, has been developed, which enables the orientation occurring in the mechanical properties, during forging, to be rendered useful to the piece that is produced. The process is primarily advantageous when a large number of similar forgings are to be produced from a single large ingot.

Adopting this process, the ingot is first forged, by upsetting, with the object of bringing about a certain orientation in the mechanical properties of the forged ingot, without necessarily paying attention to the shaping required to produce the requisite form of the forging to be made. The rough-forged ingot is then cut into blanks whose general shape resembles the outlines of the individual finished forgings, the cuts, which by their intersecting planes determine the shape of the rough blanks, being made in such directions that the direction of the desired maximum resistance to particular kinds of stresses in the finished forgings coincides with the direction in which the resistance to that kind of stresses assures preferred values in the rough-forged ingot. Thus, by this process, the planes of cutting, which determine the position of the individual blanks in the rough-forged ingot, are brought into strict correlation with the directions of the main stresses to which the finished forging is to be subjected. The application of this process is described by means of some examples.

362,834 and 362,837. G. FARBENINDUSTRIE AKTIENGESELLSCHAFT, Frankfurt, Germany, patentees: ALBERT L. MOND, agent, 19, Chancery Buildings, Chancery Lane, London, W.C. 2. Accepted December 10, 1931.

Welding Manganese Steel.

IN building-up or welding austenitic manganese steel, containing from 12 to 20% manganese, it has been customary to employ electrodes which deposit metals similar in composition to the steel being welded. Such electrodes, however, have the disadvantage that critical welding conditions are necessary, the current having to be accurately regulated, and there is a tendency for the weld metal, when worn manganese steel castings are being reinforced with new metal, to have a coarse crystalline structure. This may cause cracks to develop due to stresses set up by contraction of the metal on cooling.

Investigations have shown that steel articles can be built up with a base of austenitic manganese steel by depositing, by means of fusion welding, additional metal from an electrode or welding rod capable of depositing steel, containing from 7 to 10% nickel and 15 to 20% chromium, which is in the austenitic condition after deposition. It is claimed that this deposited metal makes a tough joint with the surface of the manganese steel.

The electrode employed, which preferably consists of a metal core provided with a flux-forming covering, such as blue asbestos, may conveniently be such that small quantities (up to about 0.5%) of tungsten or molybdenum are also contained in the deposited metal. When a blue asbestos covering is used around a nickel-chromium steel core, the latter should contain from 6 to 10% of nickel, 15 to 30% of chromium and, if desired, from 0.5 to 2% of either tungsten or molybdenum. Again, the electrode may consist of mild steel or Swedish iron wire covered with a flux containing the nickel and chromium, either as separate metals or alloyed together, and also tungsten or molybdenum, if these are employed. A suitable composition for the covering of such an electrode is made in the form of a paste containing 20% nickel, 55% chromium and 4% tungsten or molybdenum in a paste with 10% chalk. 5% fluorspar and 6% sodium silicate and the like. When such an electrode is melted in the arc, the metals in the covering or coating form a nickel-chromium austenitic steel.

The great advantage claimed for this electrode is that a reinforcement can be made which rapidly hardens on the surface when subjected to abrasive stresses, so that the resistance to wear increases as the surface of the metal is stressed. The method is particularly advantageous in reinforcing dredger buckets, tramway crossings, the jaws of rock crushers and cement grinding machinery, which are invariably made of manganese steel.

363,018. THE QUASI-ARC COMPANY, LTD., and E. F. NEWELL, both of London, patentees: Messrs. Gill, Jennings and Every-Clayton, 51/52, Chancery Lane, London, W.C. 2, agents. Accepted December 17, 1931.

Austenitic Chromium-nickel Steels to be Welded.

THE austenitic chromium-nickel-alloy steels are liable to become differentially oxidised when exposed to the temperatures and conditions experienced in welding. This results in a modification of composition and texture which may be detrimental in their resistance against corroding media, and is a serious disadvantage to plant in which welding has been employed. The addition of vanadium or titanium (vanadium being preferred) to austenitic chromium-nickel steels, in which the carbon content is not less than 0·07%, enables the welding to be carried out without the unfavourable effects of heating. The quantity added should be such as to enter into stable chemical combination with the carbon dissolved in the austenitic basic mass, so as to bind the carbon itself and retain the austenitic texture of the steel alloy, even when it is subjected to a heating, which is equivalent to an annealing treatment.

Austenitic chromium-nickel steel, containing 10—20% chromium, 6—14% nickel, 0·07—0·25% carbon, with 0·3—0·9% titanium, and with or without 0·3—1·5% tungsten, is particularly designed for welded vessels for use in chemical processes. Such vessels made from this steel, in which the weld contains substantially the same proportion of chromium as the original steel, is claimed to possess a high degree of resistance to the action of certain corroding media, particularly lactic acid, acid-ammonium sulphate, and solutions of alum and aluminium sulphate.

The beneficial effect of the titanium when welding is performed is believed to be due to the fact that it is preferentially oxidised by the gases present during the welding operation, and thus preserves the chromium content of the steel. It has been found that on welding this steel containing titanium the chromium content remains practically the same after welding. A suitable alloy for fabrication by welding contains 18·0% chromium, 8·0% nickel, 0·13% carbon, and 0·6% titanium. This alloy is claimed to possess great ductility and maximum resistance to corrosion. Where tungsten is added to this composition a suitable proportion is 0·6%.

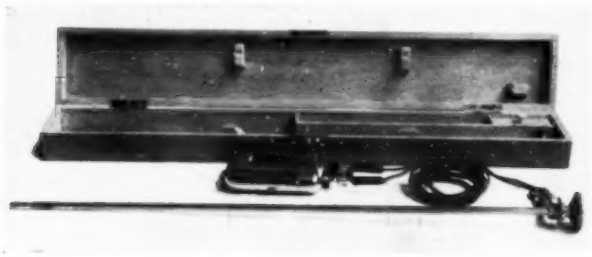
362,902. W. H. HATFIELD, D.Met., Sheffield, and H. GREEN, Rotherham, patentees. Messrs. Boult, Wade, and Tennant, 111 and 112, Hatton Garden, London, E.C. 1, agents. Accepted December 4, 1931.

Recent Developments in Tools and Equipment

EXAMINING THE INSIDE OF TUBES.
Some Details of an Interesting Instrument.

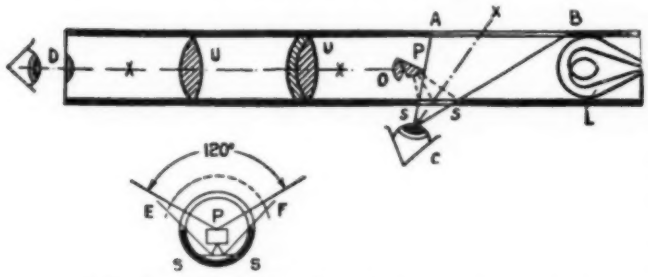
A VERY old problem in engineering has been to devise some method of inspecting the inside of machinery and apparatus of all kinds, for detecting flaws and irregularities when the space is extremely limited, and also the distance considerable. The inspection at leisure of any portion of the inside of condenser tubes, gun barrels, and similar difficult enclosures is, for example, of the utmost value.

Such operations can now be carried out with ease and accuracy by means of the "Introscope," which is manufactured by the Foster Instrument Co., of Letchworth (Herts.). This is already in extensive application for examining the inside of tubes of all kinds, such as used for condensers and boilers, hollow shafts, turbine rotors, rifle barrels, gun bores, and gas bottles and cylinders and other high-pressure containers. Also important uses, to mention a few only, are the examination of turbine blades without opening the turbine casing, and of internal combustion engines for aeroplanes, motor-cars, and motor-launches.



Small "Introscope" set complete with case.

LONGITUDINAL AND TRANSVERSE SECTION OF THE INTROSCOPE TO ILLUSTRATE THE PRINCIPLE.



A–B. Inspecting slot in the tube.
C. Imaginary position of the eye viewing the illuminated slot area A–B as actually seen.
D. Eye-piece.
E–F. Angle of objective O.
L. Tiny electric lamp.
O. Wide-angled objective.
P. Prism.
S–S. Auxiliary mirror.
U–U. Reversing lenses.

Essentially, the instrument consists of a polished nickel tube of extremely narrow bore, in many cases less than $\frac{1}{4}$ in. diameter, like a rod, and of any desired length. At one end is an eye-piece, and at the other a slot or aperture with a tiny electric light bulb enclosed in the tube, which is also connected near the eye-piece by a flexible wire to the electric light mains or an accumulator. The instrument is then inserted into the condenser tube, or other object, and on looking through the eye-piece the small area of surface above the aperture will be seen brightly illuminated. In this way, by moving the instrument about every portion of the surface can be examined systematically with great accuracy. This is achieved because of the use, on the most ingenious lines, of a series of extremely small lenses, along with a mirror and a prism, fixed inside the tube, at intervals reflecting the light from one to the other until the eye-piece is reached.

As already indicated, the electric lamp is at the end, and illuminates the surface being examined through a slot aperture in the instrument tube. An image of this illuminated surface is transmitted to a prism by a horizontal auxiliary mirror in the bottom of the tube, and then by the prism to a wide-angle objective, from which the image is transmitted direct to the eye by a series of reversing lenses of any desired number, according to the length of the instrument. The eye sees the portion of the surface opposite the slot that is illuminated, according to the situation of the tube, just as if it was looking directly at the surface through the eye-piece. Also, since the light from the electric lamp strikes the surface obliquely any minute irregularity is thrown up in high relief.

The smallest standard size of the "Introscope" is 5·0 mm. outside diameter (0·197 in.) and 600·0 mm. long (23·62 in.), but, as stated, any length of tube can be supplied, according to the conditions.

A typical example of the value of this instrument is in connection with the Schneider trophy and the world's record of 408·8 miles per hour attained by a British seaplane. This, it may be remembered, was of the "S 6" type, made by the Supermarine Aviation Works (Vickers), Ltd., Southampton, who stated that the "Introscope" was used for examining the tanks, oil coolers, and other portions of these seaplanes, and was found indispensable in ensuring that no hidden flaws were present, a vital matter, of course, under the exacting conditions of such a terrific speed.

Micarta Roll-neck Bearing Lining.

MANY efforts have been made from time to time to increase the working life of roll-neck bearings. Babbitt, brass, and bronze alloys have been the most common materials used in steel mills, although in recent years lignum vitæ wood bearings have shown certain merits, having a lower coefficient of friction and greater enduring qualities. Comparatively recently, however, a composite material known as Micarta has been developed which possesses superior physical properties. Trial experiments were made with this material in 1930 in a rod mill, and the promising results obtained caused further investigatory work to be concentrated upon it with the object of producing a Micarta bearing of proper design, uniform in structure, relatively cheap to manufacture, and easy of application. This has been accomplished by moulded arcuate segmental construction, in which the filling threads of the cloth, which forms the base of the material, are radial in all parts of the segment. The edgewise grain direction with equal thread distribution in all parts of the bearing results in uniform wear.

This material has very low frictional properties, is uniform in structure, does not have the tendency to seize after a shut-down, and does not require special handling to prevent shrinking and cracking. With regard to durability, it is of interest to note that the first bearing installed is still in service after a record of over 3,500 hours of rolling, equivalent to fifty times the average service of brass. This service is perhaps of an exceptional character,

but other installations in which difficulties have been encountered with brass and lignum vitæ bearings have given ten times the life of brass when Micarta has been used.

The lower frictional properties of the material are most marked at linear speeds above 200 ft. per minute, and wherever speeds in the range above 200 are encountered, and bearing pressures are not too severe, it may be adopted with advantage. Certain types of mills, such as rod, wire, strip, sheet bar, and smaller merchant shapes, offer these conditions. For lubrication it has been found that water is all that is required. The water can be applied in the conventional manner used in cooling the necks, or it may be fed into the bearing similar to force-feed systems. Where the cooling water is applied on the necks, rounding or bevelling the edge of the Micarta and providing suitable grooves is recommended, to allow for easy access of water into the bearing. Oil or grease will not harm the material, but in the ordinary application the use of water only is advocated. Pressure oil-feed systems should give good results with Micarta, although nothing of this nature has as yet been tried.

Where the nominal arc of bearing area is 120° a very economical construction is possible. In the majority of mills this arc is reasonably close to 120°, so that this advantage in economy can be utilized. In many cases where end thrust is severe the thrust collar wears out more rapidly than the radial liner, and separate replacement of this thrust block is possible, thus ensuring maximum life for the bearing. Since the Micarta bearing lining is somewhat different from the conventional design of brass or wood, it is necessary to modify the chocks to accommodate it. Therefore, whenever possible, the Brightside Foundry and Engineering Co., Ltd., Sheffield, who are responsible for this development, recommend that this be done even for a trial application. However, if for any reason it is not desirable to do this, plate material of the same fabric base can be furnished to fit the particular case. The material will be furnished to provide end grain wear on the bearing surfaces. For regular installations the moulded type lining is more economical.

Steel Treatment by the "Macrome" Process.

SOME considerable time ago we made reference to a new process for the treatment of tool and other steels, known as the "Macrome" process. Since then important developments have been made with the process in several directions. The process is applied to finished steel products of any analysis, whether composed of carbon or alloy steel. It has the effect of toughening the steel, enabling it to resist vibration for longer periods. Treatments by the process mainly consist of the utilisation of heat and electricity in conjunction with variations in periods of time to produce greater cohesion in the crystalline structure, which gives increased tenacity, uniformity, and stability to steel.

The process is carried out at low temperatures, consequently no distortion takes place, and the liability to crack or fracture is eliminated. It is therefore applicable to tools made for the finest and most exact work, as it does not alter the size or shape. Some indication of the effect of the process on a tooth-forming milling cutter made of a 14% tungsten high-speed steel is given in the following test result :—

	Length of Cut before Sharpening became necessary.	R.P.M. of Cutter Arbor.	Feed in Inches per Min.	Depth of Cut.
	In.			In.
As originally heat-treated	136	60	3	0·45
After treatment	*768	60	3	0·45

* The cutter not then requiring re-sharpening.

The results of many other tests could be given, but all indicate the remarkable effect produced, and show the value of this treatment in reducing working costs, in some cases by 50% or more. No adequate idea of the increased power for work given to the finished steel products by this treatment can be obtained from mechanical and other laboratory tests, but we understand that instruments for detecting the beneficial action are being developed. The inventor informs us that he has obtained the greatest increased longevity of resistance to destructive working stresses, in steel and other metals, through considering the subject mainly on biological lines, and that the process gives a positive and active cohesive power to metals, increasing their resistance to destructive forces, which seem to bear a close resemblance to the vital resilience possessed by organic creatures.

There is no doubt that this process will be considered by many as unorthodox and revolutionary in theory, but it is claimed to be evolutionary in practice, and the results so far obtained are sufficient proof that the treatment profoundly and advantageously affects finished steel articles in a manner which cannot be accomplished by any heat-treatment. It is of interest that many Continental firms of high standing are sending tools over to this country for treatment by the process, and at least one motor engineering firm have definitely adopted the process as a standard practice. We understand that the Admiralty are now contemplating trials of tools on a production basis in consequence of investigations carried out on its behalf, while records of many trials carried out under normal working conditions by railway companies and other important engineering firms show the beneficial effects of this treatment. Those who are interested and desire to give it a trial should get into touch with Messrs. A. C. Wickman, Ltd., of Coventry, who have undertaken the agency for the process in Great Britain.

Electric Welding Possibilities in Shipbuilding.

SHIPBUILDING is one of the most interesting occupations so far known to man, said Mr. N. M. Hunter, in giving some notes on steel shipbuilding at a meeting of the North-East Coast Institution of Engineers and Shipbuilders on March 11, on account of continual change and development. Just now, he stated, it seems we are on the eve of what may turn out to be a revolution in ship construction by the development of electric welding, for not only has it been proved a practical proposition to produce the all-welded ship, but, in fact, some builders are prepared to quote an alternative and cheaper price for a ship built by that method. Such rapid progress has recently been made in electric welding apparatus, electrodes, and methods, that it appears possible now to produce a structure by this means which is not only stronger than the riveted structure, but about 12 to 20% lighter.

He hoped this subject would receive the most careful consideration of the great classification societies, and that they would approach it from a research point of view with the object of assisting both builders and owners to take full advantage of this new method of construction which now gives promise of being an improvement on existing methods.

The advantages which appear obvious in considering electric welding as applied to steel ship construction are : Strength combined with lightness ; the absence of all danger of leakages on account of eliminating the riddling of the plating with innumerable holes which have to be filled up with rivets or by other means ; and the absence of all caulking, which, at the best, is destructive to the solidity of the riveted overlap by the burring-up of the edge of one plate and the consequent hollow space caused between the two plates of the joint. This prising-up of one plate from the other, which is inevitable in all caulking, tends also to reduce the friction of one plate on the other and so reduce the practical holding power of the joint.

The author also visualised possibilities of lightening not only the hull through the elimination of connecting flanges, overlaps, rivet heads, etc., but also the framework of the machinery where it might be possible to introduce a light welded steel structure as rigid as the present comparatively heavy and clumsy cast-iron framework.

Test Results and Service Values of Materials.

THE pure scientist is primarily concerned in ascertaining facts, the philosopher, on the other hand, is interested in determining values. Facts and values may be regarded as two phases of the substance of knowledge, and the engineer cannot ignore either of these phases. He must have knowledge of facts—knowledge never exact, but of the highest degree of precision available—and he must know the significance of the facts. This twofold interest was considered by Professor H. F. Moore at a joint meeting of the A.S.T.M. members in the New York Metropolitan District and other technical societies on February 18 last. He directed his attention more particularly to test results and service values of metals, and referred to tests in actual use, in which the precision with which the test results can be obtained is far higher than the degree of certainty as to the significance of the tests as indications of service value. Three examples of such tests include the various tests for ductility, impact, and resistance to corrosion. When we consider ductility as an index of value of steel to be used in a structure, the fact must be faced that specifications demand an enormously greater degree of ductility than the metal would ever have to withstand in a structure, while the question of the significance of test results for ductility is still more difficult for machine and structural parts subjected to repeated loading. Impact has always been a mystery word in engineering mechanics, but at just what speed of application of load the mechanical resistance of material begins to change materially is a problem which has a different answer for every different kind of material. While the meeting of an impact test on a notched specimen is a very simple matter, the significance of this impact test is a matter of much complication and uncertainty.

Perhaps no service value of materials, especially metals, is so hard to determine by test as is resistance to corrosion. There are many kinds and degrees of corrosion, and short-time high resistance to severe corroding agents can be determined quickly and fairly accurately, but this determination is of no value in determining long-time resistance to a mild corroding agent of another kind. At present all accelerated corrosion tests are regarded as of very doubtful reliability in determining service values.

The accuracy, uniformity, and significance of several typical laboratory test results were considered which included tensile strength and compression. For ductile metals the tensile strength does not have any very direct significance, and their ultimate compression strength is impossible to determine. Elastic limit, proportional limit, and yield-point are terms used, somewhat loosely, to denote the limit of pure elastic action in the metal. For most metals, however, there is a region below which the action of the metal is almost purely elastic, and above which distinct plastic action predominates. The values obtained by various tests for elastic limit, proportional limit, and yield-point, when carefully analysed, seem to be arbitrarily determined values lying within this range.

In recent years two new limits of strength have been given much attention. The first of these is the endurance or fatigue limit, a limiting stress below which a material will stand an indefinitely large number of cycles of stress without failure. It would seem that this limit has a direct bearing on the ability of a material to withstand repeated stress. The endurance limit apparently has considerable significance in metal for springs, shafts, axles, wire rope, railway rails, and many other machine and few structural parts.

The second new limit is the creep limit at elevated temperatures. This is different from plastic flow, which takes place at the yield-point, for such plastic flow does not continue indefinitely under steady load. Whether for any metal there exists a limit below which the creep is zero for a given temperature is as yet uncertain. The whole subject of creep is such a recent development that it is not possible to say how important this test will be or whether any short-time tests will become feasible, but it gives promise of great significance as a test value in connection with metals which have to carry stresses at high temperatures.

Professor Moore stressed the need of every testing engineer keeping alive his interest in and his study of the technique of testing, and also of the service significance of test results.

Effect of Iron upon the Mechanical Properties of Duralmin.

DATA on the effect of iron upon the tensile strength and hardness of duralumin containing 4·6% copper, 0·5% magnesium, 0·6% manganese, 0·3% silicon, and from 0·22 to 1·5% iron, are given by W. Kroenig in *Zeitschrift für Metallkunde*, vol. 23, No. 9, 245-249. The test-samples cut along the rolling direction from sheet metal 2 mm. thick were kept at the annealing temperature (500° to 540° C.) for 30 mins., and then quenched in water of room temperature. The tests were made shortly after quenching, and after storing the quenched samples for ten days. The samples rich in iron had a lower tensile strength than the low-iron samples, both after quenching and storing. The difference in strength was the greater the higher the annealing temperature was. For instance, after quenching from 500° C. and storing, the alloy containing 0·22% iron showed a strength of 28·1 tons per sq. in., and the alloy containing 1·5% iron 24·4 tons per sq. in. After quenching from 540° C. and storing, the strengths of the same alloys were 30·1 and 24·2 tons per sq. in. respectively. However, the increase in strength after storing was about the same, irrespective of iron content. The elongation values remained nearly unchanged, being about 22%, with the alloys containing from 0·22 to 1·1% iron, and from 18 to 19% with the alloy containing 1·5% iron. The hardness of the samples also decreased with increasing iron content. However, the increase in hardness after storing was greater with the low-iron samples, particularly with the higher annealing temperatures.

With increasing iron content an increase of inclusions could be stated under the microscope. Up to 0·9% iron, these inclusions were of eutectic structure, which could be revealed by etching the samples with an aqueous solution of 7% HF and 27% NHO_2. Over 0·9% iron, bright bluish-grey primary crystals appeared, showing numerous cracks. From the fact that these crystals were not attacked by 20% H_2SO_4 at 70° C. after 3 mins., it can be concluded that they have a more complex composition than corresponds to the formula $FeAl_3$. The fall in strength and hardness with increasing iron content is explained by the author by the fact that part of the $CuAl_2$ which, according to the precipitation hardening theory is responsible for the increase in strength, is retained by the iron in the form of a eutectic, thus being prevented from entering into solid solution.

Re-magnetising Magnetos.

A type of magnetiser has now been placed on the market by the Witton-Kramer Tool and Hoist Works of The General Electric Co., Ltd., which should prove of value to garages or works in which repairs to magnetos are carried out. The magnetiser embodies many interesting features of design, not the least of which are the adjustable and adaptable pole-pieces, which can accommodate bar magnets up to 12 in. in length and horse-shoe magnets of practically any size. Its chief advantage, however, lies in its capability of re-magnetising old magnetos without the necessity of dismantling them, the operation simply consisting of placing the magneto between the poles and switching on the magnetising current.

The equipment is designed to operate from direct-current only, the total power consumption being very small (3 kw.) Switching the current "on" and "off" is performed by a foot-operated pedal switch fitted with heavy contacts and magnetic blowout. This form of switch allows the operator to have both hands free for changing the magnets. Five or six switchings with the pedal are usually sufficient to magnetise any form of magnet.

BRITISH STANDARD SPECIFICATIONS

Cast-iron Spigot and Socket Drain Pipes.

THE new specification recently issued for cast-iron drain pipes (B.S.S. No. 437—1932) is the fifth specification of a series dealing with cast-iron pipes for water, gas and sewage. It provides for straight pipes only. Drain fittings have not been dealt with in the first issue, but it is hoped that it will be possible to provide for these in a future edition. The pipes are specified in standard lengths of nine feet, exclusive of the depth of socket. The standard weights are inclusive, and satisfy the requirements of the London County Council Drainage By-Laws.

The external shape of the socket of the pipes is not specified beyond the limits given in a table. Inquiry at the commencement of the work revealed considerable variation in pattern and, in view of the numerous connections with which these pipes are used, and the expense in which the industry would be involved by adopting a standard external shape, it was agreed for the present to specify only the minimum requirements.

Dimensions of Black Bolts and Nuts.

THE demand for a British Standard for Black Bolts and Nuts, subsequent to the withdrawal of B.S.S. No. 28, in 1924, led the Institution to issue separately the table of dimensions for black bolts and nuts which appeared previously in B.S.S. No. 28. It has been felt, however, that, for an engineering commodity of such general use as black bolts and nuts, a definite British Standard Specification was necessary, and this need has now been met by the publication of B.S. Specification No. 28—1932, Black Bolts and Nuts, Studs, Lock Nuts, and Washers, which has just been issued by the British Standards Institution.

The wide application of such bolts in every section of engineering industry will make the specification of almost universal interest. It provides for bolts of diameters from ¼ in. up to 6 in., and gives the dimensions for the heads, lock-nuts, and washers, and the length of the screwed part. Tolerances on the width across flats, and on the thickness of the heads and nuts are also given. In view of the fact that the dimensions previously given for black bolts and nuts are still referred to in the trade as the dimensions of B.S. Specification No. 28, it has been felt desirable to issue the new specification under this number in spite of the fact that originally it also provided for bright bolts and nuts and spanners.

Copies of Specification No. 437—1932 and the revised specification No. 28—1932, may be obtained from the Publications Department, British Standards Institution, 28, Victoria Street, London, S.W. 1, price 2s. 2d. each, post free.

Pulverised Fuel Firing.

THE general considerations affecting the direct-fired systems and central systems of pulverised fuel firing, with special reference to power-station practice, were given in a paper by S. B. Jackson, A.M.I.E.E., M.Inst.F., before the members of the Institute of Marine Engineers. The former system, it is suggested, is obtaining considerably increased application in all countries, principally due to the lower initial expenditure. Part of the paper covers an examination of the combustion process, and it is shown that high calorific value lower ash content coal of uniform grading, as delivered to the burner, provide the most suitable conditions for ensuring efficient combustion. The author stresses the importance of pre-heat and turbulence, and also that the bare tube wall ensures the highest heat liberation.

Trends in mill design, the importance of drying, and the selection of suitable fuels are discussed. Some principal advantages of powdered fuel are considered in detail, and a table showing a comparison of stoker-fired and pulverised fuel station thermal efficiencies is given. Aspects of dust and sulphur emissions are subjected to examination, and the opinion is expressed that public attention to these considerations, whilst desirable, may have a far-reaching influence on the location of generating stations or the cost of production of electrical energy.

The subject of costs is examined, in which connection it was formerly urged that there was a need for the standardisation of the methods of calculating the cost of production in electrical generating stations. This need has now been met. Past influences of pulverised fuel on boiler design are outlined, and the major considerations affecting future development are indicated. The conclusion is drawn that pulverised fuel firing will find increased application, and that rival systems of firing may be eventually displaced.

Catalogues and Other Publications.

We have received a very attractive folder from the English Steel Corporation, Ltd., giving particulars of their "Immaculate" stainless and heat-resisting steel, together with a brochure containing full information on Immaculates 1, 2, and 7. These stainless steels have a continually increasing application to general engineering purposes and can be supplied in many forms. With suitable heat-treatment tensile strengths can be obtained over a range of 45/115 tons per square inch. Users of special steels can obtain these publications from the offices of the Corporation at Sheffield.

Brown, Bayley's Steel Works, Ltd., of Sheffield, have recently published a number of folders and leaflets showing the behaviour of their stainless steels with a number of commonly used chemicals, and the application of these steels for a wide range of acid-resisting purposes. Reference is also made to "Twoscore" brand of stainless steel, which is useful where the general corrosive conditions are too severe for ordinary stainless steels.

The "N.C." brand of high-temperature resistance wire, manufactured by Messrs. Brunton's (Musselburgh), Ltd., is supplied by the sole selling representatives, The Electrical Equipment and Carbon Co., Ltd., 107-111, New Oxford Street, London, W.C. 1, who have sent us particulars of this material together with the resistance and current-carrying capacities of various sizes. They will send a copy to anyone interested.

The February issue of *The Welder* is a special B.I.F. number, and gives in detail particulars of some of the exhibits which were shown by Murex Welding Processes, Ltd., at the Birmingham section of the Fair. Of outstanding interest in this issue is an article by Dr. J. H. Paterson on "Mechanical and Physical Properties of Weld Metal." Other important articles include "Welded Steel Structures," by Hope A. McCreadie, C.E.; "Magnetic Influence on Electric Welding," by J. E. Kennard; which make this issue both interesting and informative. Copies may be obtained free of charge on application to Murex Welding Processes, Ltd., Ferry Lane Works, Forrest Road, Walthamstow, E. 17.

The *Nickel Bulletin* for February contains an informative article by M. Paul Sabatier on "Nickel as a Catalyst in Chemical Reactions": further articles deal with "Nickel Catalysts in the Hydrogenation of Oils," "Readily Machinable Welds on Cast Iron," as well as the British Industries Fair, in addition to the useful features usually associated with this publication. In making application for copies readers are asked to note the new address: The Bureau of Information on Nickel, The Mond Nickel Co., Ltd., Thames House, Millbank, S.W. 1.

We have received an attractive folder, giving particulars and applications of fractional horsepower motors from Metropolitan-Vickers Electrical Co., Ltd. There are many point of outstanding merit associated with these motors which, together with their wide range of usefulness, should interest makers of small machines designed to be driven by electricity. This folder may be obtained from the offices of the Company at Trafford Park, Manchester.

Business Notes and News

Structural Steel Recommendations Accepted by the L.C.C.

The London County Council has put into force the code of steelwork practice recommended by Sir Robert Tasker's Committee. This Committee, which was appointed to report on the amendment of the London Building Act, has acted with the greatest promptitude in recommending to the London County Council a code for the use of steel in buildings based upon the findings of the Steel Structures Research Committee of the Department of Scientific and Industrial Research. The code has also been accepted by the British Standards Institution as the basis of a British standard specification on the use of structural steel in building.

The new code has been based on research extending over two years, and eminent authorities have collaborated in this effort, which has produced for the country a code of practice based on the high standard and reliability of British standard steel. It provides a valuable contribution to the establishment of an economic basis of building, and by opening up the vast field of building it will give fresh life to the steel industry as well as the numerous other industries that depend upon steel, such as coal, coke-ovens, blast-furnaces, iron-ore mines, and transport. In view of the lead given by the London County Council it is hoped that local authorities throughout the country will adopt the code.

Explosive Crushing of Minerals.

A new process is being developed for crushing minerals by the application of force within the mineral rather than from forces applied without. According to the United States Bureau of Mines' Report of Investigations, 3118, J. Gross and R. S. Dean have discovered a process which marks a notable advance in the art of recovering commercially valuable minerals from the relatively worthless rock in which they occur. The principle of explosion crushing is applied which depends upon the expandable substance contained within the pores of a solid body, on the expansion of which the body will disrupt. Such expansion may be obtained by the detonation of an explosive, or by the sudden release of pressure of a superheated liquid. Investigations have shown that it is possible to shatter the ore by the explosion of steam induced into the honeycomb-like internal structure of the mineral. This decrepitation results in separating a large part of the mineral from the rock in more or less powdered form prepared for final reduction.

The expense of this new process is stated to be comparatively small, the cost of the explosive energy used being calculated at 1 cent per ton of ore as compared with the previous expense for fine grinding of 5 to 10 cents per ton, including rock and mineral.

A Recent Tin Development.

At a recent extraordinary general meeting of the British-American Tin Corporation, Captain Oliver Lyttelton, who presided, outlined an interesting development. The meeting was held for the purpose of approving a scheme for the formation of a new company to be called the British Tin Investment Corporation. This company will acquire all the assets of the British-American Tin Corporation—except metallic tin, which is being sold to a smaller company—as well as new holdings which are being acquired from certain new interests. At the end of the first stage the new corporation will have as liabilities 1,750,000 ordinary shares of 10s. each, £875,000, and a loan of £127,404, and as assets shares in tin-mining companies £939,904, formation expenses, say, £3,000, and cash £59,500. With the exception of an important number of shares in Consolidated Tin Smelters, Ltd., the shareholdings will be almost all in the Malayan tin-dredging industry. Captain Lyttelton believes they are representative of the best and lower-cost producers, and they will be carried in the books of the new corporation at the market price of November 30 last, or slightly below the current value. Thus the British Tin Investment Corporation will be a holding company having important interests in a large number of Malayan tin undertakings, and it will presumably have relations with them somewhat similar to those existing between, say, the Central Mining and Rand Mines companies and the gold-mining undertakings with which they are associated.

Instruction in Metallurgy and Foundry Work.

It is of interest to note that a recent report of a sub-committee of South Staffordshire contained the following resolution:—"That this Advisory Committee on Metallurgy and Foundry-work, representing a large number of firms in South Staffordshire, having examined the equipment of the department and noted the quality of the students, is convinced that in the interests of local industry, which employs several thousands of operatives, the work of the college should be fully maintained and, wherever possible, should be extended. It feels that expenditure has been carefully controlled, and that an excellent return is obtained in the improved technical equipment of the local trades. It is convinced that a reduction in the activities of the college would be seriously detrimental to the industries of the neighbourhood, which urgently needs skilled operatives and leaders.

We congratulate Wednesbury Technical College for earning a report of this character, which is a testimonial to the efficiency of the instruction given, and at the same time indicates the close relationship existing between the industry and the work of the College. The need for capable instruction in our technical colleges was never greater than the present.

Steels in the "Blue Bird."

The world's speed record, set up by Sir Malcolm Campbell with his car the "Blue Bird," is another indication of the remarkable development that has been effected in design, and in the manufacture of materials capable of withstanding high stresses to which they are subjected under such conditions of use. It is interesting to note that the English Steel Corporation, who have been associated with the world's records in the air, on water, and on land were responsible for much of the steelwork in the "Blue Bird," including the massive chassis assembly, the crankshaft of the Napier engine, the front and rear axles and the gears, all of which were made from this firm's range of high-tensile alloy steels.

The chassis assembly of this car is a particularly interesting piece of engineering work. The construction is unusual and consists of two side members similar to the pressed-steel members used in ordinary automobile practice, but heavier, joined by tubular cross members. These side members are made from steel sheet, ¼ in. in thickness; the depth is 11 in.; overall length, 16 ft.; and the six tubular cross members are made as forgings. The whole assembly, including the sub-frame members, brackets, spring shackles, and all nuts and bolts used, is made of 3% nickel steel, and it is produced to unusually fine limits of accuracy.

New Standard Price List of Files and Rasps.

Seventeen years have now elapsed since the file manufacturers brought into operation their last standard price list of files and rasps. During this period certain anomalies and inaccuracies in the list prices of 1915 have become apparent, and with a view to correcting these, and also arriving at some measure of simplification, the British and American file manufacturers have agreed upon a new price list on the practical basis of actual cost of manufacture of each type and size of file, which they put into operation as on and from March 1, 1932. Further, it is anticipated that the German file manufacturers, who are also in agreement with the new list, as a result of negotiations with the British and American makers, will adopt, eventually, this new standard list. It is interesting to also note that file manufacturers in Austria, Czechoslovakia, France, and Sweden have cordially approved of the principle underlying this new price list, and these countries are hoping in the near future to adopt it, thereby making this list truly an international one.

It was felt that a large number of the sizes which appeared in the 1915 price list were redundant and unnecessary, and considerable simplification has been introduced in the new list. It is, of course, appreciated that in certain instances special sizes may be required, and whilst such unlisted sizes may be quoted for and made to order, they will be charged for at the price of the next higher size listed; but it is anticipated with confidence that users of files and rasps will adopt the sizes listed as standard for their future requirements.

This new price list came into operation on the first of this month, and all orders dated on and after this date will be executed at the new prices.

Some Contracts.

The following contracts for tramway materials have been placed by the Sheffield Tramways and Motors Committee:—Cargo Fleet Iron Co., Ltd., Middlesbrough, 500 tons manganese-steel tramway rails, 500 tons chromium-steel tramway rails, and 300 pairs fish-plates; T. Bolton and Sons, Ltd., 1,550 copper bands; Coghlan Steel and Iron Co., Ltd., Leeds, 180 pairs fish-plates and 1,000 sole plates; English Steel Corporation, Ltd., 1,100 pairs fish-plates; Messrs. G. Cooper and Sons, 3,000 tons fish-bolts, nuts, and washers; Ibbotson Brothers and Co., Ltd., Sheffield, 2,000 anchor bolts, nuts, and plates; Edgar Allen and Co., Ltd., Sheffield, double-junction renewals; and Hadfields, Ltd., double-junction renewals and fifty car-wheel centres.

The Ioco Rubber and Waterproofing Co., Ltd., Glasgow, a subsidiary company of Vickers, Ltd., have secured an order for rubber-flooring the new electricity showrooms, which the Glasgow Corporation are erecting in Waterloo Street, Glasgow. Upwards of 4,500 sq. yds. are specified in the contract.

Messrs. Blackstone and Co., Ltd., Stamford, have received contracts for four pumping sets for Caister sewerage, five sets for Runcorn Rural District Council, and engine-driven portable pumping sets for five different authorities.

The Cleveland Bridge and Engineering Co., of Darlington, have secured a contract for a bridge over the Forth, which is estimated to cost about £230,000.

Messrs. Walter Firth, Ltd., have secured a contract for the laying of mains and the erection of a pumping-station at Multby-le-Marsh, in connection with the Mablethorpe water scheme of the Mablethorpe Council. The water tower is to be erected by Messrs. Wm. Wright and Son (Lincoln), Ltd.

Messrs. Worthington-Simpson, Ltd., have been awarded a contract worth £4,000, for machinery and pipework at the pumping-station of the Guildford Town Council.

The Davenport Engineering Co. have secured a £7,000 contract for additional cooling towers at Canning Town generating station.

The Woodall-Duckham Vertical Retort and Oven Construction Co. (1920), Ltd., has received an order from the Portsmouth Gas Co. for an installation of Woodall-Duckham intermittent vertical chambers. The installation will consist of 35 chambers capable of carbonising 262 tons of coal a day with all chambers working. The contract also includes coal- and coke-handling plant, and a waste-heat boiler is to be installed capable of dealing with the whole of the waste gases from the settings.

Messrs. Aeroto, Ltd., London, have booked a number of orders for their patent screw-type fan. These include orders from Messrs. Serck Radiators, Ltd., Birmingham, for fans for use in cooling transformer oil; from Messrs. Roan Antelope Copper Mines, Ltd., for several fans for their mines in Southern Rhodesia; from Messrs. J. and E. Hall, Ltd., Dartford; for Aeroto-type fans for the Leicester Co-operative Dairies; from the Bank of England for ventilating its new building; from the Hollywood Masonic Hall, Belfast, and also the Masonic Peace Memorial Building, Great Queen Street, London, W.C. 2.

Contracts for files and rasps have been placed by the Admiralty with a number of Sheffield firms:—Thos. Firth and Sons, Ibbotson Bros. and Co., Sanderson Bros. and Newbold, the English Steel Corporation, J. J. Saville and Co., and Samuel Osborn and Co.

The Service Motor Works, Belfast, have received an order stated to be worth £28,000, from the Belfast Town Council for the reconditioning of 30 tramcar bodies.

Sir William Arrol and Co., Ltd., of Glasgow, have received from the Rhodesia Railways, Ltd., the order for an 80-ton overhead electric travelling crane for the Mafeking works.

The following contracts for tramway equipment have been placed by the Highways Committee of the London County Council:—Thomas Firth and John Brown, Ltd., Sheffield, 1,500 pony wheel tyres and 1,500 driving tyres; English Steel Corporation, Ltd., Sheffield, 1,500 pony wheel tyres and 1,500 driving tyres; Monk Bridge Iron and Steel Co., Ltd., Leeds, 400 tramcar tyres; British Insulated Cables, Ltd., 13,000 copper bonds; Joseph Harrington, Ltd., steel nuts and track insulators; Electric and Ordnance Accessories Co., Ltd., Hanley, Staffs, 15,000 porcelains for track insulator standards.

The Egyptian State Railways Administration have awarded a contract to the Talbot-Stead Tube Co., Ltd., Walsall, for steel boiler tubes of various dimensions—275 of one dimension, 7,000 of another, and 1,400 of a third dimension—at a total cost of £2,163 19s. 2d.

Fodens, Ltd., of Sandbach, have received an order for four "Foden," speed-six, 6-ton pneumatic-tyred steam wagons, fitted with three-way tipping bodies, and one 5-ton pneumatic-tyred end-tipping trailer, for the Kent County Council.

Messrs. The English Electric Co., Ltd., Stafford, have been awarded a number of contracts for omnibus bodies and also for trolley omnibuses. The Corporations of Preston, Hull, Wallasey, Bournemouth, and Northampton have ordered double-deck omnibus bodies, and the Preston and Hull Corporations single-deck bodies in addition. The Southend Corporation has ordered two double-deck and the Notts and Derby Traction Co. ten single-deck trolley omnibuses on A.E.C. two-axle chassis. In the case of each order the bodies and electrical equipment will be manufactured by the English Electric Co.

Messrs. Vickers-Armstrong, Sheffield, and Hadfields, Ltd., have received orders from the Admiralty for bullet-proof plates.

Messrs. Stewarts and Lloyds, Ltd., Glasgow, have been awarded a contract, valued about £21,000, for the supply of 4,500 yds. of steel tubing, bitumen-lined internally and sheathed externally, by the Preston Town Council.

Messrs. H. Farrow, Ltd., London, have been awarded a contract for the construction of water tanks and pumping-station, worth £38,000, for the Ilford and Barking Joint Sewerage Committee.

Messrs. Reid, Ferens and Co., Newcastle-on-Tyne, have secured a contract for the erection of 50 miles of overhead wires from Northallerton to Easingwold, in connection with the electrification scheme of North Yorkshire.

The Hawker Engineering Co., Kingston-on-Thames, have received an order from the Danish Ministry of Marine for two torpedo aeroplanes.

Messrs. Swan, Hunter, and Wigham Richardson, Ltd., of Wallsend-on-Tyne, have received an order from the Inter-Provincial Steamship Lines, Ltd., of Halifax, Nova Scotia, for a steamship of 2,575 tons for service between St. John (N.B.), Halifax, Quebec, Montreal, and the Great Lakes.

Leyland Motors, Ltd., Leyland, Lancs., have been awarded a contract by Cardiff Tramways Committee for 15 motor-buses, namely, ten double-deck 40/50-seater "Titan" vehicles at £1,525 each, and five single-deck "Tiger" buses at £1,090 each.

Iron and Steel Institute.

The following changes on the Council have taken place:—Mr. Arthur Dorman has been elected a Vice-President, and Captain H. Leighton Davies, of Guest, Keen, Baldwins, Ltd. and Dr. A. McCance, Managing Director of the Clyde Alloy Steel Co., have been elected Members of the Council.

THE IRON AND STEEL TRADES.

Of actual improvement in the position of the iron and steel trades during the past month there has been little indication, although in some areas there has been a better feeling, based largely on tariff expectations. The 10% duty which came into operation at the beginning of March will not, it is anticipated, afford much real assistance to the iron and steel producing industries themselves, although in the case of certain of the consuming branches the 10% may help to consolidate the benefit which accrued to them as a result of the departure from the gold standard last September. Iron and steel producers, however, are looking for tariff assistance on a broader basis in the near future. No official announcement on this point has yet been made, but it is generally anticipated with some degree of confidence that the case of the iron and steel industries for a large increase in the duties on foreign materials will be the first to be considered by the Tariff Commissioners.

Midland foundry iron makers have been able to report little expansion of contract sales during the past month, although at the moment of writing indications of a broadening of interest on the part of some of the more favourably situated consumers are not wanting. At the same time, it is satisfactory to be able to report that in the aggregate the tonnage of Midland makers delivered to users' works was not appreciably smaller last month than it was in January. On the other hand, Scottish makers of pig iron continue to complain bitterly of the keen underselling by Indian brands, which are being offered for delivery into many of the principal using districts, including Scotland itself, at very much lower prices than are being indicated for Scottish foundry iron. North-East Coast makers are reported to be dealing with rather more inquiry on export account. As with the Midlands area, producers on the North-East Coast are managing to dispose of considerable quantities of iron in associated foundries, and the statistical position is, therefore, much more satisfactory than it otherwise would be. There has been no price alteration in respect of foundry iron during the past month. As regards the future, the indications are that any movement is more likely to be upward than in the reverse direction.

Only very moderate activity is reported in any section of the finished iron trade, with the lower grades for the nut and bolt and other industries especially quiet. Here again the quotations for crown and better quality bars have maintained a very firm front, although in the case of the lower quality material severe price cutting in an attempt to meet the competition for foreign bars has been reported.

The steel trade is making very slow progress towards a return to more normal conditions. Activity in the shipyards is at a very low ebb, and with the large reduction in public expenditure the constructional engineering industry continues to suffer, the consequence being an extremely poor call for steel materials. In the latter branch, however, a number of structural concerns are reported to be now handling a larger flow of inquiries, and the prospects of some degree of early improvement are regarded as brighter. There has been no sign as yet of any improvement in the locomotive building industry, which is operating generally at a disappointingly slow rate, nor in boiler making, and the demand for steel from both these directions leaves much to be desired. Special alloy steel makers are, for the most part, doing a moderate volume of business. As with foundry iron, steel prices have been steady generally.

With regard to imported iron and steel materials, the past month or so has been characterised by feverish activity in the attempt to get in supplies before the general tariff came into operation. This abnormal flow has now ceased, and the demand for Continental products has reverted to relatively dull conditions. Immediately after the application of the 10% tariff offers for delivery to various points in this country strengthened accordingly, but it is doubtful if the advance can be long maintained. Already there have been reports from different markets that part of the rise has been lost, although this may, of course, have been due to some extent to the recent appreciation in the exchange value of the pound.

PRIEST FURNACES
for Forge, Drop Stamp and Continuous Billet Heating; for shipyard and boiler-plate reheating ..... for all Heat-treatment, including Annealing and Normalizing.
We are experts in the design and installation of Melting Furnaces for Steel, Iron and Non-Ferrous Metals.
It will be in your interest to consult us for your requirements for Drying Stoves and for Industrial Heating of all kinds.
PRIEST FURNACES LTD.,
ALBERT ROAD :: :: MIDDLESBROUGH.
'Phone: Middlesbrough 3981. 'Grams: "Priest, Middlesbrough."

MARKET PRICES

ALUMINIUM.

98/99% Purity	£95	0	0

ANTIMONY.

English	£42	0	0
Chinese	29	10	0
Crude	22	0	0

BRASS.

Solid Drawn Tubes	lb.	9¼d.
Brazed Tubes	lb.	11¼d.
Rods Drawn	,,	8¾d.
Wire	,,	7¾d.
*Extruded Brass Bars	,,	4⅝d.

COPPER.

Standard Cash	£33	5	0
Electrolytic	37	10	0
Best Selected	36	5	0
Tough	35	15	0
Sheets	66	5	0
Wire Bars	39	5	0
Ingot Bars	39	5	0
Solid Drawn Tubes	lb.	10d.	
Brazed Tubes	,,	10d.	

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	1	11½
		Plus 20%		
‡Ferro Tungsten	,,	0	1	8½
		Plus 20%		
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2-4% Carbon, scale 12/- per unit	ton	36	12	0
NOMINAL: 4-6% Carbon, scale 8/- per unit	,,	27	10	0
NOMINAL: 6-8% Carbon, scale 8/- per unit	,,	24	15	0
NOMINAL: 8-10% Carbon, scale 8/- per unit	,,	24	10	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/6 per unit	,,	40	5	0
Guar. max. 1% Carbon, scale 15/- per unit	,,	43	0	0
§Guar. max. 0.7% Carbon, scale 15/- per unit	,,	54	2	6
‡Manganese Metal 96-98% Mn.	lb.	0	1	3
‡Metallic Chromium	,,	0	2	6
§Ferro-Vanadium 25-50%	,,	0	12	8
§Spiegel, 18-20%	ton	6	17	6
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	6	5	0
20/30% basis 25%, scale 3/6 per unit	,,	8	17	0
45/50% basis 45%, scale 5/- per unit	,,	12	12	6
70/80% basis 75%, scale 7/- per unit	,,	17	5	0
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	12	5	0
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
Ferro Phosphorus, 20-25%	ton	21	10	0

FUELS.

Foundry Coke—						
S. Wales	£1	2	6 to	1	7	6
Sheffield Export	0	18	0 to	0	18	6
Durham	0	14	6 to	0	15	0
Furnace Coke—						
Sheffield	0	12	0 to	0	12	6
S. Wales	0	17	6 to	0	18	0
Durham				0	14	6

GUN METAL.

*Admiralty Gunmetal Ingots (88:10:2)	£52	0	0
*Commercial Ingots	43	10	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb. 0	0	9½
*Cored Bars	,, 0	0	11½

LEAD.

Soft Foreign	£12	13	9
English	14	15	0

MANUFACTURED IRON.

Scotland—						
Crown Bars, Best	£10	5	0			
N.E. Coast—						
Rivets	11	0	0			
Best Bars	10	10	0			
Common Bars	10	0	0			
Lancashire—						
Crown Bars	9	15	0			
Hoops	£10	10	0 to	12	0	0
Midlands—						
Crown Bars	£9	15	0 to	10	0	0
Marked Bars	12	0	0			
Unmarked Bars	—					
Nut and Bolt Bars	£8	7	6 to	8	12	6
Gas Strip	10	12	6			
S. Yorks.—						
Best Bars	10	10	0			
Hoops. Hoops	£10	10	0 to	12	0	0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	9½d.
*Cored Bars	,,	11½d.
†Strip	,,	10½d.
†Sheet to 10 W.G.	,,	11d.
†Wire	,,	12½d.
†Rods	,,	11½d.
†Tubes	,,	1/4½
†Castings	,,	1/1½

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—						
Hematite M/Nos.	£3	8	6			
Foundry No. 1	3	12	0			
,, No. 3	3	9	6			
N.E. Coast—						
Hematite No. 1	3	5	6			
Foundry No. 1	3	1	0			
,, No. 3	2	18	6			
,, No. 4	2	17	6			
Cleveland—						
Foundry No. 3	2	18	6			
,, No. 4	2	17	6			
Silicon Iron	3	1	0			
Forge No. 4	2	17	0			
N.W. Coast—						
Hematite	3	14	6			
Midlands—						
N. Staffs Forge No. 4	3	1	0			
,, Foundry No. 3	3	6	0			
Northants—						
Forge No. 4	2	17	6			
Foundry No. 3	3	2	6			
Derbyshire Forge	3	1	0			
,, Foundry No. 3	3	6	0			
West Coast Hematite	4	3	6			
East ,, ,,	3	4	6			

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron	97 Krona.					
Billets	£12	18	0 to	£16	6	0
Wire Rods	£14	18	0 ,,	£17	17	6
Rolled Bars (dead soft)	£10	8	0 ,,	£11	15	0
Rolled Charcoal Iron Bars	—			£16	6	0

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£28	0	0			
,, Braziery	24	0	0			
,, Wire	—					
Brass	21	0	0			
Gun Metal	24	0	0			
Zinc	6	10	0			
Aluminium Cuttings	62	0	0			
Lead	11	0	0			
Heavy Steel—						
S. Wales	2	5	0			
Scotland	1	18	6			
Cleveland	1	15	0			
Cast Iron—						
Lancashire	2	4	0			
S. Wales	£2	5	0 to	2	7	0
Cleveland	£2	2	6 to	2	5	0
Steel Turnings—						
Cleveland	1	12	6			
Lancashire	1	2	6			
Cast Iron Borings—						
Cleveland	1	6	0			
Scotland	1	12	0			

SPELTER.

G.O.B. Official		—	
Hard	£10	10	0
English	13	12	6
India	12	0	0
Re-melted	11	0	0

STEEL.

Ship, Bridge, and Tank Plates—			
Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	9	0	0
,, ,, (Marine) ,,	—		
,, ,, (Land), N.E. Coast	10	0	0
,, ,, (Marine) ,,	10	10	0
Angles, Scotland	8	7	6
,, North-East Coast	8	7	6
,, Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	0	0
Light Rails	£8	10	0 to 8 15 0
Sheffield—			
Siemens Acid Billets	9	2	6
Hard Basic	£8	2	6 and 8 12 6
Medium Basic	£6	12	6 and 7 2 6
Soft Basic	6	0	0
Hoops	£9	10	0 to 9 15 0
Manchester—			
Hoops	£9	0	0 to 10 0 0
Scotland, Sheets 24 B.G.	10	5	0

HIGH SPEED TOOL STEEL.

Finished Bars 18% Tungsten Extras	lb.	2/9
Round and Squares, ½ in. to ¼ in.	,,	3d.
Under ¼ in. to ⅛ in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ⅛ in.	,,	3d.
,, ,, ½ in. × ¼ in.	,,	1/-

TIN.

Standard Cash	£130	12	6
English	131	15	0
Australian	131	17	6
Eastern	134	12	6
Tin Plates I.C. 20 × 14 box	0	16	0
Block Tin (Cash)	138	5	0

ZINC.

English Sheets	£24	10	0
Rods	29	0	0
Battery Plates	20	5	0

* McKechnie Brothers, Ltd., quoted Mar. 8. † C. Clifford & Son, Ltd., quoted Mar. 8. ‡ Murex Limited, quoted Mar. 8

Subject to Market fluctuations, Buyers are advised to send inquiries for current prices.

Prices quoted Mar. 8, ex warehouse.